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Evaluation of Supply Chain Performance

A Manufacturing Industry Approach

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With respect, admiration, and Love,
I dedicate this book to all the people who helped me to identify my own potential, which I did not even believed possessed.

Especially To:

God. He is who giving peace to my life.
My daughter Andrea Sifuentes, she is my daily motivation and my best life project.
My husband Ernesto Sifuentes, he is mine major pillar and support, and the best competition of overcoming.
My parents Mariía A. Sosa and Arturo Avelar, they who sowed in me a great seed of superation. My sisters and brother, they have taught me the value of the family.
My teachers, colleagues, students, and friends for their advice and teachings.

Liliana Avelar-Sosa

Humans take inspiration when they set a goal. To me, my family is my inspiration, which is why I dedicate this book to:
God. I thank Him for everything.

My parents, my life teachers.
My to my children (Jorge Andres García-Rodríguez and Mariana Odette García-Rodriguez) reason to be of my life, my greatest pillars and strengths.
My wife, Ana Blanca Rodríguez-Rendon, for her unconditional support in all the projects I undertake.
My brothers and sisters, who taught me the best lessons at home.
My brothers who recognize me and accept me as such.

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I dedicate this book to my parents who have been an example of strength and love on the struggles o life. Thanks for all your support.

Aidé Aracely Maldonado-Macías

Foreword

Supply chain management has experienced a rapid evolution as a subdiscipline inside operation management; it is well known that successful world-class companies compete fiercely with their supply chain's performance. In this manner, a critical aspect of successfully managing the supply chain lies in measuring and observing the proper factors that conduct higher benefits. Export-oriented manufacturing industries in developing countries such as México face an even greater challenge in the race for competitiveness, and the performance evaluation approaches applied for them present a great opportunity for research.

Accordingly, the book is divided into three parts. Part 1, Competitive Aspects of Supply Chain encompasses Chaps. 1–4. Chapter 1 presents the concept and importance of competitiveness for the supply chain. This chapter introduces the topics of competitive advantage and comparative advantage in supply chain's performance. Chapter 2 presents additional relevant concepts for a global approach of modern supply chain management and improvement. Chapter 3 introduces the reader to the manufacturing industry in Mexico and its transformation; it helps to understand the context of this research and offers an overview of this industry in developing countries, and Chap. 4 explains the relationship between the supply chain and the export-oriented manufacturing industry and discusses how this relationship can impact the ability of companies to stay competitive in a global market. Additionally, an overview of the most common supply chain evaluation approaches in the export-oriented manufacturing industry is presented.

Part II is entitled Supply Chain Performance Factors and includes Chaps. 5–8. Chapter 5 debates about the concepts related to supply chain performance and supply chain performance evaluation. Companies around the world are continuously searching for a wide range of benefits for competitiveness; in this pursuit, several supply chain attributes play an important role and the proper metrics must be employed for their evaluation. The chapter explains how these attributes and metrics are classified from a financial perspective and how an operational, tactical, or strategic approach can be used to describe the qualitative and quantitative aspects of the supply chain. In Chap. 6, these factors associated with supply chain performance in the manufacturing industry are explained. The main concepts and the overview of the elements that impact on the supply chain performance are discussed. In this manner, some important topics, such as supply chain risks, manufacturing practices, and regional factors are extensively explained. Chapter 7 describes the performance factors associated with benefits in the supply chain considered in this book. These attributes present relationships with financial and no financial performance. Some attributes include flexibility, agility, customer service, transportation, quality, delivery times, inventory, and financial performance. Chapter 8 discusses some of the most used supply chain evaluation methodologies in the industrial environment. The first chapter addresses the multivariate techniques and then the regression and factor analysis techniques. These methods are needed to understand the methodology proposed in Chap. 9 for determining the critical factors on supply chain performance for achieving competitiveness in manufacturing industry.

Finally, Part III presents the Impact of Competitiveness Aspects on the Supply Chain. Chapter 9 describes the complete methodology for validating latent variables which will help define and measure the constructs needed in this research. This step precedes the determination of structural equations models to establish the relationship among variables and determine their impact on the declared dependent variables. Proper interpretation for each model is provided with respect to the impact of these variables on supply chain's performance. Chapter 10 makes an exploratory analysis of the data collected in the research and discusses the aspects used to measure supply chain risks, manufacturing practices, and regional impact factors. Statistical data of 225 questionnaires are reported, out of which the 67% are companies with more than 500 employees, and the 29.8% are of automotive industrial sector. Chapter 11 presents the effects of manufacturing practices and risk factors on supply chain performance through structural equation models to consider the relationships between three types of supply chain risk factors—supply risks, demand risks, production process risks—and supply chain performance indices. Chapter 12 explains the impact of regional aspects on supply chain performance. Specifically, these aspects are: regional infrastructure, regional costs, services, service quality, and the role of the government as regulator. Simple and more complex models are developed to understand the influence of these aspects on achieving supply chain performance benefit variables. Chapter 13 explores the Regional Impact Factors with supply chain performance benefits. Main results indicate that aspects such as infrastructure and government support are important for companies to operate, yet they cannot be controlled inside of the facilities and depend on external forces. In his manner, they are the cause of uncertainty for companies. Chapter 14 explores the impact of manufacturing practices on supply chain performance. The relation between four management strategies for manufacturing are studied, total quality management, just in time, maintenance and advanced manufacturing technology. The results show that advanced manufacturing technologies present a significant contribution in achieving better results in the process and in quality control.

Finally, Chap. 15 presents the impact of manufacturing practices on the performance of the supply chain, for example, in agility and flexibility. Furthermore, this chapter shows an integrator model that summarizes all the contents explained in this book, since it is, perhaps, the most important contribution. The integrator model points out the impact that risk factors, regional impact factors, and manufacturing practices present to the performance of supply chains for exportation. Therefore, some conjectures are validated, such as the fact that to improve the competitiveness of a company, it is necessary to consider the features of the environment, where it operates. For example, it can be considered the Government participation, supporting companies, available infrastructure, services, or qualified task force among many others.

We genuinely believe that this book contributes to increase the knowledge of the supply chain attributes and their relationship with main benefits to remain competitive. Accordingly, this book offers specific strategies to improve the supply chain performance and the metrics to develop reliable actions for continuous improvement among all the supply chain members. Therefore, we widely recommend it for being very useful to students, decision makers, researchers in academia, and professional engineers working in these areas. We hope that you find its lecture not only useful but also enjoyable and help you in your profession to visualize a new perspective of modern logistics for manufacturing industry.

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Preface

Nowadays, globalization has made supply chains more complex and brings important challenges related to products, customer locations, suppliers, transportation requirements, trade regulations, and taxes on international trade. All these challenges appear from the beginning of the production process, yet companies, as inherent elements of the supply chain, must work to simplify the supply chain stages and process as much as possible to increase earnings and achieve success. To the largest extent possible, and according to the particular characteristics of each supply chain, it is important to reincorporate new business strategies to transform the organization and guarantee its survival and competitiveness. A supply chain consists in many parties and production stages (Liu and Liu 2017). More explicitly, a supply chain involves a system of organizations, people, activities, information, and resources working together for moving a product or service from supplier to customer. In a supply chain takes place the transformation of natural resources, raw materials, and components into a finished product that is provided to the end customer (Kain and Verma 2018). The study of supply chains starts in the early 1990s when old business paradigms must be changed due to globalization. Nowadays, companies around the world recognize that they can gain competitive advantage through its supply chain proficiencies. However, supply chain of export-oriented manufacturing industries in developing countries such as Mexico present peculiarities of interest and very little has been published about them. Competitiveness in exporting manufacturers is a hot topic for scholars and industrialists alike in their pursuit of the best recipe for higher profitability within an uncertain and dynamic competitive environment. However, the legal and government institutions that nowadays regulate the economies also have an important role in the implementation of long-term economic development projects that provide not only long-lasting competitive strategies, but also ways to systematically improve these strategies, thereby reinventing their ability to enter complex global value chains successfully. The competitiveness of exporting companies in Mexico largely depends on the global value chains in which these companies participate. That said, these companies must comply with specific tasks, forms of work, basic knowledge requirements, experience, abilities, and skills (including foreign language skills) to produce better products at lower costs and with timely deliveries. This allows them to move from a regionally competitive industry to an internationally competitive sector.

This book presents a quite complete approach for increasing the knowledge of the logistics and supply chain management of these industries. Export-oriented manufacturing industries entail intensive mounting processes that requires majorly handwork. They arose from the presence of Mexico into the North American Free Trade Agreement (NAFTA) with the USA and Canada, facilitating the exportation of their products. As a result, logistic activities among these industries have increased their relevance due to the movement of import of raw materials and export of finished goods thru their supply chains (Avelar-Sosa et al. 2015).

Once this context is explained, the book presents the conceptualization of the supply chain performance in which several performance indicators are described and the evolution of these measurements is overviewed. Additionally, in order to conduct evaluation practices, several factors must be considered. In this way, those related to supply chain's performance in the manufacturing industry are widely discussed in twosome chapters. Accordingly, the book presents several risk management perspectives and risk assessment methodologies. Accordingly, evaluation approaches for supply chain performance have proliferated in the literature and this book has compiled the most accepted methodologies. Nevertheless, the book proposes an entire methodology to determine the relationship among supply chain factors with their corresponding benefits using structural modeling. It also includes an integrative model to clarify these relationships and determine direct, indirect and total effects to quantify the impact of these factors to obtain mayor benefits.

During its 15 chapters, this book offers valuable information that encourages companies to evaluate their supply chain performance and proposes a complete methodology to achieve this goal as well. A competitive world requests for the best companies, and this book is offering a clear methodology to determine those specific factors that impact companies' profits.

In this manner, we believe that this book is the ideal way for spreading knowledge among decision makers, postgraduate students, academics, researchers, and other professionals interested in the improvement of supply chain performance and manufacturing industries around the world. We have confidence that readers can find our work useful, interesting, innovative and a real contribution to improving supply chain performance in manufacturing environments.

Ciudad Juárez, Mexico

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Part I
Competitiveness Aspects of Supply Chain

Chapter 1
Conceptualization of Supply Chain Competitiveness

1.1 Evolution of the Concept of Competitiveness

Corporate competitiveness is the most pursued economic benefit in this globalized era. It is commonly addressed by economist and politics around the world (Pérez-Moreno et al. 2016). The origins of competitiveness date back to the fifteenth and seventeenth centuries and emerged from the economic theory known as mercantilism. Mercantilism stated that the way a country could produce wealth was mainly through foreign trade, and to this end, the rule was that "the value of what is sold to foreigners annually must always be greater than our domestic consumption of products" (García Ochoa et al. 2017). However, in 1776, Adam Smith's classical theory opposed to this perspective that viewed trade as a zero-sum game. To address the deficiencies of mercantilism, Adam Smith proposed an economic model that considered trade as a sum-sum game in which all traders could obtain benefits with minimum unit costs.

After Adam Smith's theory, Eli Hecksecher's neoclassical theory emerged in 1919, and then, Bertil Ohlin's theory in 1993. Both gave rise to the factor endowment theory, which claims that all nations share the same technology, but each nation has different factor endowments (Jones 2011). This principle means that a country or region can be a net exporter of the relatively more abundant factorial products and/or services, and a net importer of those relatively scarce factorial goods and/or services (Nyahoho 2010).

Eventually, the modern economic theory emerged from Krugman's classical principles (Krugman 1979) to argue that competitiveness does not depend only on a country's factor endowments, but also on labor capacities, specialized infrastructure, and supplier networks, among others. As a result, Porter (1990) proposed his competitiveness theory by claiming that "*Prosperity depends on a country's competitiveness, which is based on the productivity with which the country produces goods and services.*" In other words, strong macroeconomic policies and solid, legal institutions are necessary but not sufficient to guarantee prosperity.

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Instead, competitiveness is grounded on a country's microeconomic principles, which are the level of sophistication of corporate operations and strategies and the quality of the microeconomic environment where companies compete.

Authors such as Rugman (1991) and Dunning (2003) strongly opposed to this view of competitiveness, since the approach only took into account the country of origin and neglected the geographical scope of multinational corporations and the role of the government as an endogenous factor. Consequently, Porter's model of competitiveness was extended to the generalized double diamond model that presents a country's competitiveness by using two diamonds: one of them represents the domestic environment (i.e., microenvironment), and the other stands for the international environment (i.e., macroenvironment), where variables such as government and multinational/global corporations interact.

Later on, Cho et al. (2009) argued that Porter's model lacked physical and human factors and proposed the so-called nine-factor model. The model claims to be more comprehensive and more dynamic. As physical factors, the nine-factor model embraces the four endogenous factors of Porter's diamond model, and for the human factors, the authors included workers, professionals, entrepreneurs, politicians, and bureaucrats. Additionally, the model of Cho et al. (2009) conceives randomness or uncertainty as the exogenous aspect. Then, the authors aggregated two more elements—the domestic context and the international context—to address the geographical scope and proposed the so-called dual double diamond (DDD) model, which incorporates Porter's original model, the nine-factor model, and the DDD model. This model is currently used by the World Economic Forum to evaluate a country's competitive performance measures.

Figure 1.1 illustrates the DDD model proposed by Cho et al. (2009). As can be observed, the model explains human factors at the national competitiveness level but not at the international level. Therefore, it is important to propose models that do not only explain the international perspective, but which also interact with domestic competitiveness aspects; otherwise, it might be impossible to accurately study competitiveness. That said, the DDD model is an important contribution to

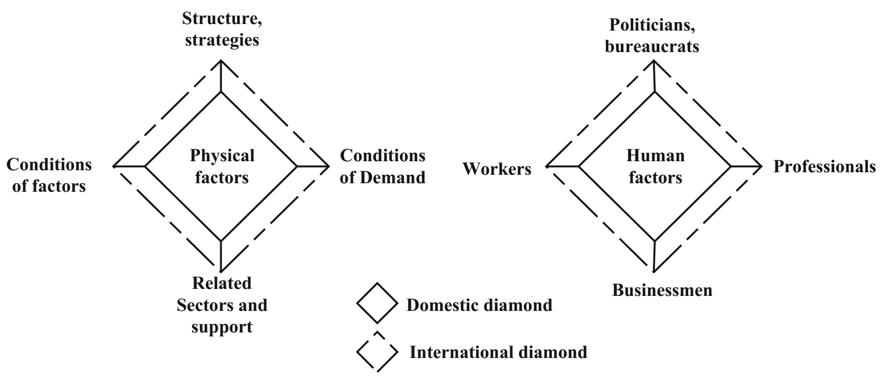

Fig. 1.1 Dual double diamond model. Adapted from Cho et al. (2009)

the global economy, since countries and regions with particular attributes can easily adapt to it. Evidently, some countries have a better condition in terms of physical factors, whereas others would be stronger in human factors, but overall, the model can comprehensively explain the aspects involved in competitiveness.

The models and theories discussed above demonstrate that competitiveness can be contextualized and applied from many perspectives. However, it is also possible to provide a general definition in which competitiveness, at the corporate level, refers to a process involving both internal and external variables. Such variables depend on government-related situations, such as the country's infrastructure, the business environment, or externalities, in which case governments can and must take adjustment measures, and companies must strategically adapt to such measures (Pinzón 2014).

1.2 Definitions of Competitiveness

The concept of competitiveness continues to evolve has blurred boundaries and lacks a unique definition. Nevertheless, competitiveness is generally associated with advantages such as sustainability, value-added production, productivity, and cost-effectiveness. Competitiveness has been studied by a large group of people, including economists, scholars, government, organizations, and international institutions. All of them have come up with their own notion and definition of what being competitive means. This phenomenon has led to the construction of a taxonomy to classify the term into multiple and different approaches. For instance, there is corporate competitiveness, country competitiveness, urban competitiveness, and even industrial competitiveness, structural competitiveness, systemic competitiveness, and Porter's competitiveness (Cotera 2014).

In order to adequately interpret the concepts presented subsequently in this book and perform an objective analysis on supply chain competitiveness, it is important to adopt one definition of competitiveness. Below, we present a few definitions of competitiveness in the business environment. First, we propose a set of definitions for international and national competitiveness; then, we offer a set of definitions under a regional approach. Finally, we provide a series of definitions of corporate competitiveness. To a greater or lesser extent, these definitions adapt to the particular business environment; also, they allude to productivity and a better use of resources as the ways to improve products through added value.

1.2.1 Competitiveness from an International Approach

This section presents a series of definitions that refer to competitiveness from an international perspective:

- Competitiveness is a key characteristic of economic entities from the point of view of their operation in a competitive environment (Zhanna et al. 2016).
- According to the Global Competitiveness Report 2015–2016, competitiveness is the set of institutions, policies, and factors that determine the level of productivity of an economy, which in turn sets the level of prosperity that the country can earn (Schwab et al. 2015).
- International competitiveness, as defined by the Organisation for Economic Cooperation and Development (OECD), is the degree to which a nation can, under free trade and free market conditions, produce goods and services which meet the test of international markets, while simultaneously maintaining and expanding the real income of its people over the long term (OECD 2010).
- Competitiveness is the ability of a country to produce goods in order to venture in international trade (Hosseini et al. 2014).
- Competitiveness includes efficiency (compliance with minimum cost goals) and capacity (adoption of appropriate goals) to set objectives and reach them (Hallmann et al. 2012).
- International competitiveness is not precisely about company productivity and efficiency, but rather about commitment and efficiency in different sectors that increase the overall performance of an economy or national income (Schneider 2013).

1.2.2 Competitiveness from a National Approach

This section presents a series of definitions that refer to competitiveness from a national perspective.

- A country's competitiveness depends on its capacity to penetrate international markets through increased exports. It also depends on the country's ability to meet the tests of international markets in order to increase its gross domestic product and per capita income, raise living standards, eradicate poverty, decrease unemployment, and increase the real income of its people over the long term (Cotera 2014).
- The degree to national companies or industries can efficiently operate their production resources (Ezeala-Harrison 2014).
- A country's ability to create well-being and maintain a prosperous competitive environment under an evaluation process allows the country to be compared with other nations at a similar stage of economic development (Kao et al. 2008; Cho et al. 2009).
- The ability of a national economy to produce goods and services meets the tests of international markets, while simultaneously allowing its people to reach a high and sustainable living standard over the long term (Solleiro and Castañón 2005).

- Competitiveness is the ability of a national economy to produce goods and services that meet the tests of international markets, while simultaneously allowing its people to reach a high and sustainable living standard over the long term (Tyson 1993).
- National competitiveness is a reflection of a nation's capacity to attract foreign investment in the form of both financial capital and qualified human resources (Kovačič 2007).

1.2.3 Competitiveness from an Industrial Approach

This section presents a set of definitions that view competitiveness from an industrial perspective:

- Competitiveness is the ability to reach a favorable comparative position to get a higher performance than that of competitors (Fuentes et al. 2016).
- Industrial competitiveness is a measure of immediate and future capacity from industrialists to design, produce, and sell goods whose attributes, including price, are combined to create a more attractive package than similar products offered by competitors. The final judge is the market (Castellanos Machado et al. 2012).
- Competitiveness is the ability of companies to compete in a given market to increase their market share and venture in international trade through exports, while increasing cost-effectiveness and sustainable growth (Centindamar 2013).
- Competitiveness is the ability to compete, that is, to design, produce, and offer products that are superior to those of competitors, considering price and quality (Ajitabh and Momaya 2003).
- Competitiveness, in the corporate context, is the ability of companies to design, produce, and commercialize products and services with higher effectiveness and efficiency to increase their market share (Karaszewski 2008).
- Competitiveness can be conceptualized as the ability of one company, in comparison with other companies, to reach a favorable comparative position and get a higher performance (Sánchez and Bañón 2005).
- The capacity of an industry or company to produce merchandise according to specific quality standards, required by specific markets, using a level of resources that is equal to or less than those prevailing in similar industries in the rest of the world, over a period of time (Haguenauer 1989).

1.2.4 Competitiveness from a Regional Approach

Finally, in this section we provide five definitions of competitiveness treated from a regional approach:

- Competitiveness is a city's capacity to penetrate national and international markets. It is related to local growth and the increasing living standards of the people living in the region (Sobrino 2002).
- The competitiveness of regions refers to the presence of conditions that both enable firms to compete in their chosen markets and enable the value these firms generate to be captured within a particular region (Huggins 2003).
- Regional competitiveness is a region's capacity to attract and maintain firms with stable or rising market shares in an activity, while maintaining stable or increasing living standards for those who participate in it (Audretsch and Keilbach 2004).
- Regional competitiveness refers to how a region manages its resources and capacities to generate a sustained increase in business productivity and the well-being of its people (Benzaquen et al. 2010).
- Regional competitiveness is the difference in the rate of economic development across regions, and the capacity and capability of regions to achieve future economic growth relative to other regions at a similar stage of economic development (Huggins et al. 2014).

The above-mentioned definitions demonstrate that competitiveness can be approached from various perspectives; nevertheless, productivity is usually mentioned as the way to earn wealth at any level—international, national, or regional. Consequently, this book adopts a corporate–regional–national–international approach (in that order) to competitiveness to indicate the relationship between this concept and the supply chain (SC) and discuss the role of competitiveness in the global competence environment. Both topics will be thoroughly addressed in the next sections that discuss the SC in the manufacturing industry.

1.3 Competitive Advantage

The notion of competitive advantage emerged from the notion of competitiveness. It is another indicator of economic progress in a country or region. A company's competitive advantage demonstrates the organization's ability to manage its unique resources, knowledge, and attributes to reach higher performance levels than those of its competitors (López et al. 2011). That said, a competitive advantage can be seen as the degree to which a company reaches a defendable position over its competitors, considering aspects such as costs/price, quality, innovation, and swiftness to reach the market (Gunasekaran et al. 2017). A competitive advantage should reflect in the short term as companies increase their benefits. In the long term, it must lead to business growth and higher market dominance. That is, a competitive advantage must change the structure of certain production aspects to allow companies to gain higher market dominance and more benefits (Fuentes et al. 2016).

A company gains competitive advantage as it modifies its SC, or the set of activities involved in the creation, production, sale, and delivery of its products and services (Kramer and Porter 2011). Experts emphasize that many firms have failed to grasp the importance of the environment surrounding their operations. They have overlooked the opportunities to satisfy basic social needs and have failed to understand how the ills and weaknesses of the society affect the supply chain. Consequently, the main driver for industries today is to establish the necessary criteria to improve their operations and reach particularly defined competitive levels.

1.4 Comparative Advantage

Comparative advantage does not only refer to the total productivity achieved, but also to the opportunity cost associated with it. In an international trade environment, a country has a comparative advantage in the production of a good if it can produce it at a lower opportunity cost than another country (Krugman and Obstfeld 2006). In other words, a country is said to have a comparative advantage when it produces a given product in greater proportion than the value of its exports, according to its participation in global trade. In turn, a country's participation in global trade is given exogenously for locations and reflects the nation's technological capabilities, natural resources, and institutional policies that benefit more certain products (Nunn and Trefler 2013).

According to the global competitiveness report, countries compete mainly in basic requirements of infrastructure, functional institutions, workforce health, and economic stability. Additionally, they might compete in education, training, technological skills, innovation, and business sophistication (Schwab et al. 2015). Free trade can benefit two countries if each one of them exports the products in which they have a comparative advantage. For instance, electrical transmission, the Revealed Comparative Advantage (RCA) index revealed that Mexico has a comparative advantage over China in combustion engines, automobile parts, and medical equipment. On the other hand, China has a competitive advantage over Mexico in office machines, computer equipment, electrical power transmission, and furniture.

Unlike the competitive advantage, the comparative advantage involves the use of local resources to produce goods and reach a global trade in which countries can compete in minimum production costs. On the other hand, a competitive advantage is associated with a well-defined operational structure that allows an economic growth over the medium and long term. That is, a competitive advantage entails a much better business projection with high economic earnings.

1.5 Competitiveness and Supply Chain

Nowadays, globalization has encouraged a global competitive environment wherein competitiveness plays a major role. Consequently, research on competitiveness has increased exponentially and has encouraged the active involvement of corporations in competitive performance and training.

As previously mentioned, competitiveness is influenced by government policies. In this sense, there is a strong relationship between corporate competitiveness and a supply chain, since the latter is formed by all those companies capable of adding added value to a product while simultaneously managing better national and international competition (Ion and Cristina 2014). Therefore, the decisions that each SC member makes are vital to improving their competitiveness levels (Jiménez et al. 2017). In this sense, the SC can be considered as a tool for increasing corporate competitiveness and chances of survival.

The success of global CSs starts with their ability to transport raw materials rapidly, reliably, and inexpensively across regions and borders (Francois et al. 2008). In this sense, a CS has the power to improve corporate performance by developing competitiveness in a step-by-step sequence, delimiting aspects such as quality, reliability, flexibility, agility, and cost-efficiency (Ferdows and De Meyer 1990). Similarly, Ion and Cristina (2014) argue that competitiveness can be attained only if companies eliminate all the waste they produce. Waste refers to the set of activities that add no value to a product. That said, eliminating waste contributes to the creation of a sustainable competitive advantage; at the same time, firms increase business performance, efficacy, and efficiency in their primary activities.

Companies usually seek to develop comprehensive strategies for better time management to improve product delivery, flexibility, and innovation; at the same time, they improve customer service, increase earnings, and raise competitiveness. All these aspects are essential to companies that wish to survive in an extremely competitive business environment. Nowadays, the competitiveness of international corporations increasingly depends on their ability to produce and deliver products and services around the world as fast and efficiently as possible. Therefore, using the SC as a competitive weapon has become a fundamental element of strategic management processes, as companies do not compete among them anymore. Instead, as Feng argues, the competition is among SCs (Feng 2012).

The current role of the SC implies that corporate competitiveness refers—to a great extent—to SC competitiveness, since companies earn their desired economic benefits through successful SC management—first by managing their primary activities as a corporation, and then, by achieving their economic goals as a profitable business. From this perspective, it is said that there are two main competitiveness goals that companies seek to reach: to dominate the increasingly dynamic and changing market and to deliver products timely and orderly by using the least of their resources, incurring the minimum costs, reducing overall production cycle time, and meeting the required quality standards. To this end, companies must evaluate their current working environments and restructure their operations through an appropriate SC analysis.

1.6 Definition of Supply Chain

The concept of SC emerged in the 1960s, when Forrester suggested that corporate success depended on the interaction among the information flow, the raw materials, the orders, the money, the workforce, and the available machinery and equipment. Similarly, Forrester argued that the main job of managers was to understand and manage such interactions.

In recent studies, the SC is defined as a set of three or more companies linked by one or more of the upstream or downstream flows of products, services, finances, and information from a source to a customer (Qi et al. 2017). If considered as a whole, then a SC is a dynamic process involving a complex flow of information and materials that is achieved by multiple functional areas both inside and outside of the company (Surana et al. 2005). Also, to many researchers, the SC is an appealing object of study and analysis due to its role in the globalization of production operations, and because it contributes to a solid competitive advantage (Zeng and Yen 2017). Therefore, by looking at the operational, strategic, and tactical aspects of a SC, it is possible to analyze the activities of a business or corporation. As previously stated, companies do not compete among them; SCs compete among them; moreover, globalization demands an improvement of competitive strategies.

The success of a company's SC relies on the appropriate balance among human resources, processes, and the use of existing technology. This balance considers many stages. First, the production stage comprises the whole system to generate value for a given product. Then, the distribution and logistics sage relates costs with material transport, storage, and handling while simultaneously maximizing the value of the operations involved. Finally, the balance also comprises the technological and information aspects that are necessary to maintain the appropriate information flow and support the complexity, diffusion, propagation, and speed of such information.

Finally, SC management comprises the planning and management of all the activities involved in supplying and converting the raw material, including logistics and the coordination and collaboration with the other SC members (e.g., suppliers, retailers, customers, service providers) (Sukati et al. 2012). In other words, SC management involves the procurement and management of the demand inside and among the other companies that integrate the SC (Kuse et al. 2010). SC management comprises suppliers, manufacturing companies, transporters, warehouses, retailers, and customers along a dynamic operations' flow.

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Chapter 2
The Importance of Supply Chains in Global Competitiveness

2.1 Global Production

The main goal of production is to provide products and services to people to cover their basic needs. Goods and services' production involves a transformation process of raw materials, including human resources, procured materials, land, and energy, which once transformed, provide value to the final product. The origins of production date back to human history, when the early humans discovered it as a means to satisfy their needs. In the ancient period, men managed to produce things through certain procedures, human strength, and eventually, some handmade tools. As humans improved their production processes, they also improved their life quality. Then, the production rate increased, and it was necessary to create new tools, such as plows, sickles, and knives; eventually, thanks to these new methods, ancient peoples achieved great development. Also, at this time, early humans managed to fertilize soils, which increased the productivity of agricultural systems (García 2004).

During the industrial revolution, men and women sought new trade routes to commercialize their goods. Then, in Western European countries, the discovery of America made people learn about other production alternatives, such as terraced farming, used by the Inca people to secure food and prevent soil erosion. Similarly, the irrigation systems developed by the Aztecs amazed many Western people and largely contributed to the development of subsequent production systems. Simultaneously, England kept innovating in production machinery and technology, and such innovations both allowed raw materials to be transformed easily and streamlined the existing transportation and communication systems.

Overall, the industrial revolution produced a radical change in the way people produced their goods. Some of the major contributions of this era are the following:

- Replacement of agricultural systems with industrial systems.
- Replacement of manual procedures with machine procedures.
- Capital concentration and increasing industrialization.

L. Avelar-Sosa et al., *Evaluation of Supply Chain Performance*,
Management and Industrial Engineering,
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– Internationalization of markets.
– Emergence of a new social class: the working class.
– Emergence of mass production.

In subsequent periods, the works of Frederick Taylor contributed to a systematized production regime, in which the most important part of industrial management was the division of labor—i.e., the separation of a work process into a number of tasks, each one performed by a separate person or group of people. The division of labor brought important changes, as it emphasized the economic rewards of the jobs, took into account worker behavior, and improved working conditions. Also, at that time, the concept of production management emerged to conceive a customer or client as one of the cornerstones of production. Not only was it important to produce large amounts of standardized products, but also to meet the needs of the customers through good quality. Eventually, operations' management arose and incorporated the concept of intangible product, also known as service, and proposed a direct link between this intangible product and the role of marketing and finances. Computers also emerged at this time, along with the first automated production systems, including Tahichi Ohno's Toyota production system. All these events led to increasingly productive systems of production.

Finally, process management emerged as a discipline to focus on business operations in order to improve production systems by addressing concepts such as total quality, business process reengineering, smart organizations, benchmarking, supply chain management, and reverse logistics (García 2004). That said, process management is the overall interest of this book, and the supply chain (SC), as an element of production, is part of this discipline. SC plays a crucial role in any production system. On the one hand, it aims at coordinating the workforce and making workers work as a team to minimize costs of product storage, transportation, distribution, and commercialization. On the other hand, the SC seeks to integrate all the necessary processes to increase efficiency and effectiveness in the flows of materials, information, and assets. With so many implications, it is important to view production as a process of ongoing improvement in which new and increasingly sophisticated tools and analysis approaches are applied to increase productivity and achieve the desired success.

If production is the process of transforming raw materials, a production chain refers to a sequence of production activities performed on raw materials to transform them into a final product. Multiple actors take part in the production chain to deliver this product to the end customer. That is, some actors intervene at the production stage, whereas some others participate in the transformation or the sales processes. Definitely, each production chain can be considered as a system of economic activities (e.g., manufacturing, logistics, distribution and commercialization, services) that establish relationships among them as a result of being part of the same production process. According to Gereffi (2001), a production chain is the set of activities for the production and marketing of a product. In this sense, the competitiveness of a product depends on the efficiency of all the production activities related to the production chain.

A production chain or productive chain is different from a value chain, yet these terms are often mis-interchanged. Production chain is commonly used to refer to the network of a given brand (e.g., the production chain of clothing brand “X”), whereas a value chain is used in a less specific context, to refer to a whole industrial sector (e.g., the textile value chain). Similarly, a value chain is the sequence of activities through which a company adds value to its products or services until they reach the hands of the customer. It includes production, marketing, and the provision of after-sales services (Bianchi and Szpak 2015). From a similar perspective, in a global value chain, the actors are located across different countries, and when a production chain involves actors abroad, it is called a global production chain (Blyde 2014).

In the last three decades, production chains have become increasingly internationalized due to the participation of many countries in the different stages of the transformation, production, and commercialization processes. This change goes hand in hand with current technological progresses, the transformation of traditional businesses, and new production capacities, thereby allowing a better handling of materials, goods, and services and modifying the way countries trade among them. In this sense, it is important to acknowledge that the current economy has made the world go from an old trade system, in which goods are produced in one country and exported to another country, to a whole new trade approach, in which goods are manufactured in cross-border production networks and countries try to find a place to capture and retain most of the value generated during the entire transformation process (Baldwin 2011).

Global value chains visibly flourished in the mid-80s, in light of the so-called globalization’s second unbundling. The second unbundling of globalization was characterized by strong advances in information technologies, the reduction of transport costs, trade liberalization, and the increase of foreign direct investment (Bianchi and Szpak 2015). Also, globalization’s second unbundling caused the production processes to be spliced into different fragments that could be spread around the world. This new form of production increased the level of specialization of production activities or tasks and encouraged the inclusion of different goods in a same value chain. In other words, the world achieved a global fragmentation of production that introduced the factor of foreign value added. In this sense, most of the current global value chains emerge and survive thanks to the value added through capital and highly qualified workforce, which suggests a process of technological change.

Nowadays, developed countries are increasingly specializing in certain production activities, and the top management departments more often seek the path to a comparative advantage. On the other hand, developing countries specialize in intensive production activities, due to the increasing value of a highly qualified workforce (Timmer et al. 2014). Also, with the fragmentation of the production process, companies that manage global production chains are generally headquartered in developed countries, whereas those that supply the raw materials are located in developing countries.

As previously mentioned, the global production chain has a set of interrelated actors and comprises a sequence of activities or operations for the production, transformation, and commercialization of goods in a given environment. In this sense, global value chains connect firms, workers, and customers from all around the world through complex production and trade networks. This new international trade allows developing countries to be a part of the global economy through the so-called global networks, which are a web of connections and interdependencies among companies that make up a self-sustaining structure for the production of goods and services worldwide (Reyes and Rozo 2015). Therefore, current production processes incrementally involve global value chains covering multiple countries, each one of them specializing in a particular aspect of the production sequence (Costinot et al. 2012).

Current value chains have a particular position in the global economy. They represent 80% of the trade (Gereffi 2015), and their presence in developing countries represents 30% of the gross domestic product (GDP) (Chains 2013). Also, global supply chains are said to have two stages: the upstream stage and the downstream stage. The upstream stage usually involves the search for and extraction of raw materials and the transformation of such materials into an intermediary product, whereas the downstream stage generally refers to the processing of this intermediary product into a finished product (UNCTAD 2014). This approach demonstrates that, nowadays, the value added of a product must be consistent with the production process that occurs at each stage of the supply chain, from raw materials' supply to distribution.

2.2 The Supply Chain and Its Relationship with Global Production

Modern firms largely depend on a broad range of products and services to complete their value-added activities, and to this end, most of these companies have created large suppliers–customers networks (Sukati et al. 2012). These networks are usually connected with other networks of buyers, suppliers, vendors, distributors, retailers, transportation companies, and other intermediaries. Also, these supply chains are responsible for the flow of materials, information, and financial elements required in the production process. Additionally, the supply chain becomes more complex as they are linked to customs, land transportation companies, airlines, shipping companies, ports, warehouses, government agencies, and international trade agreements and treaties. This level of complexity has created a competitive environment and has made markets and emerging supply-chain-related needs the focus of much attention and study.

Some experts argue that to make a difference and stand out, companies need reliable supply chain design models that take into account current and emerging elements such as globalization and performance indicators (Cedillo-Campos et al.

2006, 2012; DINU 2014). On the other hand, other experts claim that the success of big companies mainly lies in their supply chain management practices, the way they use information technologies, and the quality of the information that is shared (Zhang and Dhaliwal 2009; Su and Yang 2010; Ranganathan et al. 2011; Nativi and Lee 2012; Fadzlan 2010). Therefore, as Gastelum and Ruiz (2017) mention, the rapid progress of information flows, the growth of international trade, and the emergence of electronic commerce (e-commerce), immersed in a globalized economy context and deregulated market conditions, have led to a better integration of all the activities that make up a supply chain.

Nowadays, the production process of a good is fragmented. That is, from the moment the raw material is obtained to the moment a product is offered to a customer, there are a series of production stages operating capital of different nature. Consequently, modern production operations in supply chains face several challenges but also have many opportunities to develop and grow. Such challenges and opportunities respond to a competitive environment in which companies seek to reduce costs through economies of scale.

Due to an increasing public awareness of environmental problems and the importance of sustainable and social responsibility practices, numerous approaches, methodologies, and techniques have been proposed to timely and accurately analyze how companies manage their supply chains (Gastelum and Ruiz 2017). Similarly, aspects such as green operations (i.e., operations using reusable parts and/or materials) or carbon footprint reduction are hot topics for both scholars and industrialists and bring new challenges in the analysis of supply chain behavior. However, any supply chain analysis must certainly consider elements such as market competition, supply chain coordination and integration, and strategic, well-educated, and future-oriented customers. All these elements affect the management of supply chain operations (Choi et al. 2016).

A supply chain represents concrete purposes, such as the generation of added value in each operation and a reduction of costs, which in turn lead to more sales and earnings than competitors. Rapidity and agility in every production stage can be achieved through timely and automated information, since no time is lost between one process and the other (Vilana Arto 2011).

The advantages of a synchronized supply chain are expressed in a centralized logistics structure, in which all SC members place an order in a coordinated manner. SC members convey real-time information about their inventory levels, goods in transit, and sales' data. The supplier places a production order according to the demand and by considering all the inventories of the chain as a single inventory.

Organizing and integrating the production process involves setting agreements to share physical, financial, and technological resources. Such agreements imply a commitment to being efficient to increase the performance of each supply chain member (Zerón Felix 2012). A supply chain integrated through the information flow among suppliers, producers, and distributors manages to reduce costs, create value for the final customer and, consequently, achieve a competitive advantage. This demonstrates that management and logistics are inherent in the phenomenon, and that the chain value becomes an integral part of the process (Gastelum and Ruiz 2017).

In conclusion, it only remains to say that: *The new global economy is articulated by chains of production, financing, and trade that cover many countries and regions across the world. These flows of capital integrated by transnational value chains move in a fractioned or segmented way through national economies. The new global order… changes the driver of international economic growth, from national economies to transnational corporations, and from public policy to strategic management* (Pantojas-García 2014).

2.3 Successful Companies with an Excellent Supply Chain Management

As mentioned in the previous chapter, competitiveness has encouraged companies to transform their businesses by restructuring their different production stages. In this sense, business transformation has played an important role in logistics and supply chain, since it allows companies to reduce costs and better use their resources by optimizing each part of the production process. In turn, optimizing processes allows companies not only to add value to their goods and services, but also to speed up deliveries and improve their relationships with customers.

Supply chains have been the focus of attention for many years (Huo et al. 2010), and their study has allowed experts to analyze all those activities that companies need to perform and those attributes that they need to have to make a difference and become more competitive than other companies. The role of the supply chain has become prominent among those small, medium-sized, and large companies that seek to add as much value as possible to their products and increase customer satisfaction. That said, gaining the desired competitive advantage implies improving the supply chain, first by focusing on how the SC members are interrelated and how they communicate with one another (Bhatnagar and Sohal 2005). That said, the following paragraphs of this section discuss how some of the most successful companies have become so prominent and competitive thanks to a good supply chain management.

Dell is a multinational computer technology company founded in 1983. The founder, Michael Dell, first operated it from its dormitory room at the University of Texas at Austin. Some years later, the company had the largest range of computer products, both desktop computers and laptops, based on the newest Intel® core processors; however, ten years after it was founded, and Dell suffered a major blow due to problems with its distribution network and large inventories, even though its sales had increased by 40%. Consequently, the company planned a new production and distribution model using logistics; it hence managed to reduce its inventories to zero and could produce only what was necessary, while simultaneously maintaining its performance levels. Dell does not depend on outlets to distribute their products;

it sells them by phone and online, which minimizes costs. Moreover, its production system is like a chain: when an order is received, that same night the computer starts to be produced. Additionally, Dell's assembly line is able to assemble the equipment in less than four minutes. The success of Dell lies in the fact that the components and parts used in their computers are 60 days newer than those offered by its competitors at the same time. Also, the company has expanded as a global business and has allied with many distribution companies across countries. Dell's competitive strategy is to work hand in hand with its partners (Rangan and Bell 1998).

Walmart is another big company with a well-managed supply chain. Walmart Inc. is an American multinational retailer that operates a chain of hypermarkets, supermarkets, and grocery stores. The goal of Walmart is to offer customers the goods they want whenever and wherever they want them. Under this premise, the company developed certain structures to offer customers low products every day. Walmart worked hard to develop a highly structured supply chain management system and to improve this competitive advantage to take a leading position in the market. Since the beginning, Walmart's supply chain contributed to the company's success. Before opening the first Walmart store in 1962, founder Sam Walton used to purchase a great amount of merchandise and transport it to his stores. Then, in the 1980s, he started to deal directly with producers and suppliers to decrease costs and manage the supply chain better. In 1989, Walmart was named the retailer of the decade, and since then, the company has been committed to the continuous improvement of its supply chain. For instance, through a collaboration scheme using technological tools and information systems, the company was the first to build communication networks with its suppliers to improve the flow of materials at a relatively low cost and synchronize product demand.

As can be observed, technology has played an important role in supply chain development, as it has allowed companies to predict demand, control and predict inventory levels, create new and efficient transportation routes, and manage a business's logistics, all with high precision. Now, Walmart uses radio-frequency identification tags to track the movement of goods along the supply chain as a way of managing inventory level hand in hand with its suppliers. Also, the company currently relies on *cross-docking* to effectively replenish inventory by transferring products directly from incoming semi-trailer trucks to outbound trucks without using extra storage. Undoubtedly, Walmart has revolutionized its business structure step by step by incorporating new technological tools, management models, and alliances; all these strategies have made the company number one in logistics performance and supply chain management. Walmart has gained a dominant force in a highly competitive market (Soderquist 2005; GS1-Perú 2016).

The third example is Inditex, a multinational clothing company headquarter in Coruña, Galicia, Spain. The company originated in the 1970s and owes its success to a logistic center created in Artexio, Zaragosa, Spain. The center communicates Inditex's headquarters with each one of its points of sale around the world to make production more flexible and manage invoice. After subsequent expansions, the company currently exceeds 400,000 m^2 in extension and employs around five thousand people. Inditex's logistic center is connected with 18 production plants that supply Zara's clothes through several tunnels along more than 250 km of automated lanes (Fernández 2012; Badía and Braun 2008). Delivery times take no more than 72 h and allow for store garments to be renewed constantly and replaced twice a week. Through effective and efficient information systems, Inditex's headquarters keep real-time communication and connection with all its stores and business partners around the world, from warehouses to retailers, workshops, and cooperatives. Through its open channels, this logistics system is the point of union of the processes of clothes design, purchase, supply, and inventory turnover. In other words, logistics is the fundamental gear and can paralyze all the conglomerate that gives life to Inditex (Fernández 2012).

2.4 Why Do Companies Want to Improve Their Supply Chains?

Supply chains determine the consumption of working capital: They have an impact on inventory levels, accounts receivable, and cash. If they are effective and efficient, supply chains offer valuable resources, improve deliveries, increase yields from investments, and increase the value of shareholders (Coyle et al. 2013). Therefore, a company's supply chain is a company's extension that goes beyond borders and requires constant management of products, information, and finances to become successful. This is how companies adopt their own management practices and strategies to supervise their supply chains, from the inside to the outside.

In the 1990s, two major associations encouraged supply chain study and improvement. On the one hand, the Grocery Manufacturers Association (GMA) once asked a supply chain expert organization to conduct a thorough study of the supply chain of grocery manufacturers. Once published, the study made a series of recommendations for reducing exit inventory days, from 104 days to 61 days, to save costs. Such suggestions were followed and the grocery manufacturers saved approximately 30,000 million dollars the following year. The study became important because it demonstrated that the advantages of supply chain management and improvement are applicable to all companies, not just one. On the other hand, the Supply Chain Council published a comparative analysis for 1996 and 1997 of the ten best-in-class (BIC) companies and the median companies that reported their metrics to the council. The analysis compared supply chain-related costs, which were 7% of total sales in the BIC companies but 13.1% in the median companies (Coyle et al. 2013).

Nowadays, globalization has made supply chains more complex and brings important challenges related to products, customer locations, suppliers, transportation requirements, trade regulations, and taxes on international trade. All these challenges appear from the beginning of the production process, yet companies, as inherent elements of the supply chain, must work to simplify the supply chain stages and process as much as possible to increase earnings and achieve success. To the largest extent possible, and according to the particular characteristics of each supply chain, it is important to reincorporate new business strategies to transform the organization and guarantee its survival and competitiveness.

In conclusion, supply chains are an essential element, not only to companies but also to the different industrial sectors, and they involve removing all those activities that add no value to a good or service. Supply chains give companies a sustainable competitive advantage, while simultaneously increasing business performance and efficiency and efficacy in primary activities; therefore, companies must make sure that all their processes are effective and efficient (Popa and Vlasceanu 2014). In this sense, highly competitive companies add value to the industry where they operate by improving it. In turn, as seen in Chap. 1, a competitive industry adds value to a nation's competitiveness, thereby improving the nation's economic development (Cellini and Soci 2002).

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Chapter 3
Conceptualization and Environment of Competitiveness in the Manufacturing Industry

3.1 The Manufacturing Industry in Mexico and Its Transformation

This section thoroughly describes the context of the manufacturing industry, emphasizes the importance of analyzing competitiveness in this industrial sector in Mexico, and addresses the major characteristics of the Mexican manufacturing industry. Similarly, we offer a historical summary of this sector, which flourished thanks to new trades in the decade of 1970 and contributed to the transformation of country's economy and its competitive development. That said, even though the Mexican manufacturing industry seems to have staggered, it is still an important sector for the country, and it is the source of thousands of jobs.

In industrial contexts, manufacturing is an economic activity in which a broad range of raw materials and inputs are transformed into different consumer products. The manufacturing industry comprises companies of all sizes, from small businesses to large conglomerates, which are classified according to the products that they manufacture. Also, the manufacturing sector is formed by establishments engaged in the mechanical, physical, or chemical transformation of materials, substances, and components into new products. The assembling of component parts of manufactured products is considered manufacturing, except where the activity is appropriately classified as construction. Additionally, manufacturing includes rebuilding or remanufacturing machinery, electroplating, plating, metal heat polishing for the trade and similar processes, and mixed production to obtain oils, lubricants, resins, and fertilizers. The transformation can occur in establishments such as plants, factories, workshops, maquiladoras, and houses (INEGI 2017b).

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3.2 Overview

In the twentieth century, Mexico grew economically thanks to important transformations. The country went from a predominantly rural region to a semi-industrialized one thanks to the new economic policies and to all the social, political, and economic changes that came hand in hand (Juárez and Brid 2016). After the Mexican revolution, the industrialization process began formally in the 1930s to strengthen the shaken national production structure and overcome the dependence of the primary sector and the country's political uncertainty (Rodríguez 2007). The state also began to consolidate, and then, the industrial class emerged as the basis of economic development. Historically, those have been the most economically prosperous years.

From 1936 and 1981, the economy of Mexico grew notably thanks to an import substitution industrialization (ISI) that favored the consumption of national industrial goods through export regulations. The country's economic growth was rapid and high, but the country failed to solve its long-standing inequality problems. Then, the agricultural sector deteriorated, and this problem destabilized the economic development of many regions, because the agricultural sector was the source of much foreign exchange and cheap labor force. As a result, by 1970, it was necessary to evaluate Mexico's ISI model and improve it (Juárez and Brid 2016; Sánchez and García 2015).

From 1982 to 2015, Mexico experienced economic stagnation, which was fueled by three aspects: trade opening, the lack of an industrialization strategy, and deregulation policies. These aspects made the problem larger, and Mexico was unable to create an innovative national industry with strong scientific and technological components (Sánchez and García 2015). According to Hanson (2010), this phenomenon of low economic development in developing countries is due to poorly functioning credit markets, the distortion in the supply of non-tradable inputs in the international trade, incentives to informality, and a not so dynamic manufacturing industry. These problems can be solved via reforms that promote competitiveness and the rule of law, eliminate labor market rigidity, and believe in the efficiency of the Mexican financial system (Kehoe and Ruhl 2011). Moreover, as claimed by the United Nations Economic Commission of Latin America and the Caribbean (CEPAL 2012), the productive structure of an economy is more likely to guarantee high and sustained growth as long as it meets three characteristics: (a) oriented production and exports capable of compete in the dynamic value chain segments of global markets, (b) a prominent production, with an increasing number of intensive activities in terms of innovation and high technology, and (c) a high degree of interconnectivity, with forward and backward linkages.

3.3 Trade Opening

Imports are a key element of current trade strategies, especially in Latin America, as they precede exports, and to be able to export products, companies need to import other goods (Thomas and Grosse 2005). Since the 1970s, foreign trade in Mexico began to grow thanks to the tax exception of exported transactions. In this sense, the export industry relied not only on an ISI model, but also on an approach that combined protecting the domestic market with promoting exports (Moreno-Brid and Ros 2007).

In the decade of 1980, free trade policies increased the rate of both imports and exports, and the country experienced a trade opening process that enabled it to expand it commercially. Mexico and the USA settled bilateral agreements to give Mexican companies the opportunity to extend their commercial relationships to the international markets; however, the entrance of foreign-owned multinational companies into the country was also risky, since the country had not experienced such levels of competition in years (Thomas and Grosse 2005). However, Mexico achieved a great commercial expansion thanks to the relatively weak restructuration of the production in the manufacturing industry, especially in the export industry (Moreno-Brid et al. 2006). Then, approximately in 1985, Mexico abandoned the ISI model and adopted a new, export-oriented model. As a result, the country went from being one of the most closed economies to one of the most open economies in the world (Tello 2007).

The trade opening process continued until 1994 through negotiations with economic cooperation organizations, such as the Latin American Association Integration (LAIA), the Pacific Basin Economic Council (PBEC), the Asia-Pacific Economic Cooperation (APEC), the Organisation for Economic Co-operation and Development (OECD), and the North American Free Trade Agreement (NAFTA). Then, by 2000, the rate of Mexican exported goods was seven times higher (Benítez et al. 2016; Tello 2007). For instance, from 1994 to 2010, Mexico reported increases in exports of 10.8% and imports of 9.7%. Similarly, that same year, the Mexican manufacturing company increased its exports by 11.1% and its imports by 9.3%.

Mexico's economic liberalization brought significant changes in its export and import activities. And in the 1980s, the country went from exporting only crude oil to being an export-oriented manufacturing center at the international level. In this sense, from 1985 and 1994, it was the fifth country with the highest increase in world manufacturing market share (Moreno-Brid and Bosch 2010; Moreno-Brid and Ros 2007). Nowadays, Mexico is a part of several free trade agreements (FTAs) with 44 countries, and it has signed 30 investment promotion and protection agreements and nine agreements of limited scope. Similarly, it is part of world organizations and multilateral and regional forums, such as the World Trade Organization (WTO), the OECD, and the ALADI (Benítez et al. 2016).

Exports and economic growth are strongly interrelated, and such interrelations are the focus of increasing attention in theoretical and empirical research (Fujii

Gambero and Cervantes 2013). The relationship between exports and economic growth has four origins. First, international competence stimulates production system efficacy (Feder 1983; Kohli and Singh 1989); second, exports have an impact on specialization, which allows countries to take advantage of the economies of scale (Helpman and Krugman 1985). Third, export-oriented companies tend to have the most advanced technology, and their technical progress is spread all over the economy (Grossman and Helpman 1993). Finally, by providing economies with foreign change, exports make it possible to overcome external grow constraints (McCombie and Thirlwall 1994). Overall, these four factors suggest that countries following an export-oriented economic growth tend to prosper more rapidly. Moreover, manufacturing exports contribute most to the growth of economies thanks to their dynamic demand, the behavior of their prices, and the technical progress that results from having an important, export-oriented manufacturing sector (Fujii Gambero and Cervantes 2013).

Mexico has a highly dynamic export industry and has made radical changes in its export activities to favor the export-oriented manufacturing sector. Similarly, the country has become increasingly competitive in human resources, as employees develop more technical skills and knowledge to be able to use advanced technology properly and manage activities of a modern manufacturing system that uses a wide range of industrial engineering tools.

None of the economies with a history of long-term, robust economic growth has a frozen competitive advantage. On the contrary, these economies are able to improve their competitiveness systematically through an intensive creation–destruction process. They reinvent their ability to successfully get into new and technologically complex global value chains. Also, they manage to create relationships with export companies and local suppliers, where cheap labor is not their only competitive advantage (Juárez and Brid 2016). However, industrial policies must adhere to certain performance and competitiveness measures to reduce transaction costs and strengthen existing industries with proven competitive advantages.

Mexico started a new industrial plan known as the National Development Plan as a way to bring profound changes in productivity. The plan emphasizes the urgent need to create both forward and backward links in the value chain. Such links must be stronger so as to boost the economic growth and the country's internal markets. In the greatest extent possible, the plan will increase Mexico's value (including the national value added) and will tackle the fruitless export-oriented search for growth. In this sense, the country's value will increase as much as its own production and domestic products are incorporated to cause an effect that will impact on the country's manufacturing industry. However, the National Development Plan is the biggest industrial challenge for the country. As Sarti and Hiratuka (2011) claim: "… global restructuration… was conditioned by the production and value chain management and internationalization strategies set by transnational corporations." In other words, the industrial dynamics of a country is not only determined by its ability to manufacture its own products. It is also determined by the behavior of the global trade, the role of the country's companies in the global chain, and their ability to face competition from external products.

To conclude on the implications of industrial policies, trade opening, and production changes, it is important to mention that, in the current dynamics, companies around the world can obtain great benefits as they lead new markets and overcome the challenges associated with it. Similarly, as their production rate increases, these companies become internationally recognized. As (Manyka et al. 2012) argue, the fundamental elements of the manufacturing industry are low costs, highly qualified workforce, proximity to demand, effective transport, good infrastructure, input and natural resources availability, inexpensive energy, and proximity to innovation centers. In order to create the necessary conditions for a long-term world economic growth, companies and government institutions alike must direct their efforts toward the activities that would enable them to achieve this growth (González 2014). Countries whose policies promote international competitiveness encourage their companies to seek and obtain greater benefits. Similarly, nations whose industrial and macroeconomic policies stimulate the manufacturing industry offer their companies economic profitability opportunities, promote investment, increase the national value added of their exports, take advantage, empower, and create competitive advantages, and will be successful (González 2014).

3.4 Importance of Manufacturing Industry and Numbers

As previously mentioned, competitiveness is important for the economic development of companies, and it strongly depends on the performance of global value chains that enable the trade and exchange of products to satisfy the needs of consumers around the world. Production activities in Mexico are classified into three essential economic sectors: agricultural, industrial, and services. The agricultural sector, also known as the primary sector, comprises economic activities related to the transformation of natural resources into unprocessed primary products. Usually, primary products are used as raw materials in industrial production. There are seven main economic activities involved in the agricultural sector: agriculture, livestock, forestry, beekeeping, aquaculture, hunting, and fishing. On the other hand, the industrial sector—also known as secondary sector or manufacturing sector/ industry—involves all the industrial activities that transform the raw materials into consumer goods or equipment (INEGI 2017b). The manufacturing industry is characterized by the geographical concentration of production and seeks comparative, proximity, and demographic advantages. Also, this industry contributes to urbanization and to the emergence of large and specialized industrial cities. However, because neither the cities nor the specialized regions are self-sufficient, companies must rely on broader markets, domestic or international, to buy and sell (Trujillo and Calderón 2014).

Finally, the tertiary sector comprises all those activities that provide a service, not a tangible product. Activities in the services sector include retail, bank, education, health care, real estate, tourism, transport and communication, media and telecommunications, and computer services, to name but a few (INEGI 2017b). Many tertiary activities (e.g., trade, transport, safety, health care, education, public management) have always existed, but the sector has exponentially grown and evolved since the mid-twentieth century. Nowadays, most workers do not produce tangible goods; they work on the services industry (Serrano 2011).

3.5 Mexican Manufacturing Industry: Peculiarities

The Mexican manufacturing industry can be classified into two broad categories: export-oriented and non-export-oriented. Also, overall, manufacturing activities can be classified into the ten following categories:

- Food, beverages, and tobacco products
- Machinery and equipment
- Petrochemicals, coal derivatives, plastics, and rubber
- Metal products
- Non-metal mineral products
- Textile, clothing, leather, and footwear products
- Pulp and paper industry
- Other industrial products
- Wood products
- Furniture and related products

This work will study competitiveness in the export-oriented manufacturing, because it is an important part of the Mexican manufacturing industry. The export-oriented manufacturing industry is engaged in the production and assembly of a wide range of products that go abroad, such as electronic equipment and automotive parts (Ramírez et al. 2016). Export-oriented manufacturing companies are heterogeneous in their economic activities, dynamic, and complex enough to be simply and unmistakably conceptualized. However, as a particular characteristic, the export-oriented manufacturing industry creates export products and operates with special tariffs to import the necessary raw materials, machinery and equipment, part, and components (INEGI 2017b).

Export-oriented manufacturing companies are constantly changing, negotiating greater autonomy, and trying to demonstrate that their establishments in Mexico have important, efficient, and effective production capabilities. Mexican manufacturing companies should not be seen only as an industrialization model, but also as competitive and competing organizations with their own life cycles. This perspective should allow countries to manage strategies and differentiated paths that are part of regional productive ecosystems (Carrillo 2014). Moreover, these companies adopt increasingly complex processes of productivity and technology, increase product variety, substitute older products, incorporate process innovation, seek international certifications, expand their product design and engineering capabilities, and are acknowledged for their performance in quality, environmental responsibility, and safety (Jorge 2007).

Particularly, export-oriented companies have an amazing degree of decision-making autonomy as regards the corporations of which they are a part. Likewise, they develop specific technological, organizational, and human skills and reflect an ongoing improvement. Similarly, export-oriented manufacturing relies on a wide range of supplies elaborated by micro-, small-, and medium-sized companies and contribute to the country's economic development thanks to their impact on the gross domestic product (GDP) and employment levels. That said, here lies the importance of performing a transcending and comprehensive analysis of the Mexican export-oriented manufacturing companies.

Export-oriented manufacturing did not spread uniformly in the country. Most of the manufacturing companies in Mexico produce engines, automobile parts, cars, computers, and other electronic equipment. Such products represented 58% of total exports from 1994 to 2003. Due to their importance, Mexican export activities have a strong impact on the variation of the country's GDP. For instance, while the economy shrank 4.7% in 2009 due to the exports industry, in 2010, the same sector went from representing 15% of the country's GDP to representing 33.2% (INEGI 2017c).

3.5.1 Industrial Upgrading in Mexico: An Overview

Industrial upgrading is the ability of companies to innovate to increase the value added of their products and processes (Porter 1990). To understand this concept, it is important to comprehend four concepts (Humphrey and Schmitz 2000): process upgrading, product upgrading, functional upgrading, and intersectoral upgrading. Process upgrading refers to a more efficient transformation of inputs into outputs through a reorganization of the production system or the introduction of higher technology. A clear example of industrial upgrading is the Japanese production system, based on just in time (JIT), jidoka, and kaizen philosophies. It is estimated that 35% of export-oriented manufacturing companies in Mexico rely on these philosophies and on other improvement strategies, such as Six Sigma (Carrillo and Gomis 2004).

On the other hand, product upgrading refers to moving into more sophisticated product lines in terms of increased unit values. Examples of product upgrading are Asian retailers that moved from discount retailers to department stores (Gereffi 1994), or Mexican production lines in Baja California and Chihuahua, which rapidly went from producing analog televisions to manufacturing digital ones (Carrillo and Gomis 2004).

Functional upgrading refers to acquiring new, superior functions in the chain (e.g., design, manufacturing, and marketing) or abandoning low-value-added functions to be able to focus on higher value-added activities. In Mexico, denim manufacturers located in Torreón, Coahuila, went from traditional assembly to full-package production capabilities (Bair and Gereffi 2003). Another example is vertical integration at Delphi's Technical Center in Ciudad Juárez, Mexico, which is engaged in technological research and development for the manufacturing of auto parts (Carrillo and Hualde 1998). Finally, intersectoral upgrading refers to applying the competences acquired in a particular function to move into a new sector.

As can be observed, all types of export-oriented manufacturing companies undergo technological learning processes (Carrillo 2007). In this sense, some of the companies with remarkable industrial upgrading include Delphi, Valeo, Visteon, Sony, Samsung, and Philips. They have developed research and technological development processes, namely in the field of product design. In 2002, a survey on industrial upgrading conducted by Colegio de la Frontera Norte, a higher educational institution in Tijuana, Mexico, revealed that many export-oriented manufacturers rely on original equipment manufacturing (OEM) (Colegio de la Frontera Norte 2002). Also, the survey found that Mexico has 72 foreign-owned research and technological development centers, and 26% of them perform product design functions (Carrillo 2013). Similarly, other industries have gone from being commodity traders to manufacturing high-value electronic products, such as flat screen, digital, or high-definition televisions. The level of technology used for manufacturing has increased substantially in both, moderate-value products, such as seats and televisions, and low-value goods, such as automotive wire harnesses. In this sense, the survey revealed that 56% of the manufacturing companies used the highest technology available in the market, and 40% relied on highly automated systems. As an example, on average, each surveyed company had 24 computer numerical control (CNC) machines and five robots. Such numbers reveal a technological transition that has moved current export-oriented manufacturers in Mexico from being intensive firms of unskilled labor to being technology-intensive companies (Carrillo and Zárate Cornejo 2003; Dutrenit 2006; Lara and Carrillo 2003; Rivero 2002).

The wide dissemination of best organizational strategies also brought important changes. In the 1980s, practices such as JIT and Total Quality Management flourished in the Mexican manufacturing industry, and at that time, 20% of the cross-border companies were considered as modern and cutting-edge companies (Contreras 2000). Eventually, with the development of information technologies, there were great opportunities to invest in communication networks and software. In this sense, a survey conducted by Jorge (2007) revealed that 68% of the Mexican manufacturing companies had an enterprise resource planning (ERP) system, which is a set of systems and software packages for the effective management of day-to-day business activities. Similarly, the survey revealed that many companies relied on e-commerce, especially business to business (B2B) commerce (Jorge 2007).

Manufacturing clusters emerged in the 1990s and became an evidence of the relatively complex production development achieved after years. Examples of clusters are Original Equipment Manufacturer (OEM), a company that produces parts and equipment that are usually marketed by another manufacturer, the electronic industry in Tijuana, Mexico, and the automotive industry of Ciudad Juárez, Mexico (Koido 2003). Outsourcing is another evidence of production and technological developments. This practice involves manufacturing companies handling over certain job functions to other companies instead of having an inner department or group of employees handle them. Two examples of outsourcing in Mexico are the automotive and the electronics industry, which rely on more than 100 micro-, small-, and medium-sized enterprises (SMEs) machining companies.

As can be observed, the manufacturing industry is a source of technological and innovation capabilities inside a process of technological convergence between sectors (Contreras et al. 2005). Consequently, there is a customer–supplier co-evolution process that reveals the role of engineers as carriers of industrial learning in the relationships between local companies and transnational enterprises (Hualde 2005). In this sense, Mexico has increased its institutional capacities to support the industrial development across different regions, thereby forming binational institutions in border cities (Villavicencio and Casalet 2005a, b). On the other hand, in the light of a competitiveness loss, and the increasing market dominance of countries such as China, some jobs in Mexico have emigrated and will continue to emigrate. However, at the same time that we lose a competitive advantage due to our geographical location, the responses of such a dynamic market and market regionalization measures provide new opportunities for Chinese investment in Mexico. In this sense, our proximity to the USA regains importance as a competitive strategy (Berger 2005).

3.5.2 Main Export-Oriented Manufacturing Industries

3.5.2.1 Automotive Industry

The automotive sector has always been one of the cornerstones of Mexico's industrial development. It has been supported and encouraged by numerous programs, known as automotive decrees, issued by the government to regulate automotive production and sales in the country (Brown Grossman 1999). The automotive industry, as we know it today in Mexico, is the result of a series of events and transformations, including the globalization of the automotive industry and the alignment of companies with domestic industrial policies (Miranda 2007).

Thanks to its assembly lines, Ford became the world's largest automobile manufacturer. Eventually, General Motors started to operate, followed by Chrysler, which focused on assembling vehicles for the local market. Some of the reasons why Mexico became the focal point of the automotive industry are low production costs, low transportation costs, cheap labor force, and the expectations of a market to monopolize (Miranda 2007). However, in 1960, after the first automotive decree was signed, the country changed the strategy of an industry that had initially sought to satisfy the domestic market and regulate foreign-own investment. It gave foreign-owned companies the opportunity to settle in Mexican territory. Ford was the first one to settle with two plants, then came Chrysler, Wolkswagen, Nissan, and finally, Datsun Sedan.

The 1970s were years of quality- and production-cost-related problems, and with the new trade opening and the promotion of export activities, Mexico sets new market regulation policies. These initiatives immediately failed due to the oil crisis, the devaluation of the Mexican peso in 1976, a lack of competitiveness in the industrial sector (managed by the government), and a limited technological infrastructure. Eventually, the industry was restructured thanks to factors such as technology transfer, new working conditions, fresh and brand-new solutions from the young working class, and a better-trained and more qualified workforce. All these factors made significant changes in the Mexican industrial sector (Brid and Carlos 1996; Miranda 2007; Moreno-Brid et al. 2005).

The automotive industry is particularly important in Mexico due to its quantitative and qualitative influence on the country's industrial economy. Thanks to the automotive industry, Mexico is a part of globalization and free trade (Hualde 2017). Undoubtedly, foreign-owned Mexican manufacturing companies managed to adapt to global strategies long before the restructuration of the import substitution model. The automobile manufacturing industry is considered a strategic industry in Mexico due to its dynamism (Carbajal Suárez et al. 2016). It is interrelated with other industries, such as the glass, iron, rubber, plastics, aluminum, and textile industries, which enables it to be directly and indirectly involved in them while it simultaneously creates jobs, transfers technology, and attracts investment across regions (Chamarro 2013).

The main characteristics of the automotive industry are commonly reported in the literature, which emphasizes the emergence of regional production systems that eventually encouraged vertical integration with production activities and supplier analysis (Sturgeon et al. 2008). Some researchers praise the evolution of this industry—from the installation of the first assembling equipment to the export-oriented production approach at the trade opening stage (Miranda 2007). Others have analyzed it from a regional or conglomerate perspective (Carbajal 2013; Carbajal and Jesús 2013) or have studied it from its auto part production capabilities (Álvarez and Cuadros 2012). Some other researchers have explored the growth of the automotive industry in four Mexican regions by highlighting its importance in terms of value added and employment levels (Carbajal Suárez et al. 2016).

The automotive industry in Mexico is one of the major sources of foreign investment. During the first eight months of 2017, light vehicles manufactured in Mexico were primarily exported to the USA to be later sold abroad, and they represented 76.1% of total exports. Then, exports to Canada represented 8.9%, and vehicles exported to Germany represented 2.8% (Asociación Mexicana de la Industria Automotriz 2017). On the other hand, according to the National Institute of Statistics, Geography, and Informatics (INEGI), in July 2017, exports from the automotive industry represented $9,513.2 million USD of a total of $28,809.5 million USD, that is 33.02% (AMIA 2017).

3.5.2.2 Computer and Electronics Industry

This industry culminated in the 1990s, with the flourishing of personal computers and telecommunications thanks to the modem, the massive use of the microprocessor, the growth of the Internet, the rise of electronic information and communication systems, and the tight relationship between electronic/computer systems and scientific/educational systems. The computer and electronics industry became a sort of computer capitalism and the techno-economic foundation of globalization (Dabat 2002). It includes the manufacturing of a wide range of tangible products and basic and support services, such as semiconductors, software products, automatic data processing equipment, and electronic equipment for personal, industrial, medical, military, and computer and communication services purposes.

As regards its relationship with the global market, the computer and electronics industry primarily manufactures computers, semiconductors, and telephone equipment. It is interrelated with nearly all the manufacturing industries (Latrubesse 2004). In the 1990s, global exports of electronic goods outgrew the exports of other industries, including the automotive, the chemical, and the iron and steel industries. Similarly, in that same decade, external sales of the main electronic products made the computer and electronic industry of Mexico the most prominent export-oriented manufacturing industry in the country. Tijuana's video cluster became the world's leading exporter, ahead of Japan. Between 1992 and 1994, Mexico had a surplus of electronics and a prominent presence in the global market (Latrubesse 2004).

The value chain of the computer and electronics industry has three main production stages: active and passive components, software products, and final products. In the first production stage, active components are integrated circuits, from design to encapsulation, and passive components are printed circuit boards. The second stage refers to the conceptualization, programming, coding, manufacturing, testing, and distribution of software products. Finally, the third stage includes computer equipment manufacturing, from design to packaging. The most prominent information technology companies in Mexico are IBM and HP (Hewlett Packard), but there are also multinational manufacturers, such as Flextronics, Solectron, and Jabil Circuits, and leading suppliers such as Molex and Maquiser (Ordóñez 2005). Similarly, in Mexico, the computers and electronics industry is strongly interrelated with the global electronics information industry, and in terms of productivity, it can be linked with some production activities of other manufacturing industries, such as the electrical industry (Ordóñez 2005).

In Mexico, the Secretariat of Economy (SE) promotes competitiveness in the electronics manufacturing industry through programs and plans such as the Competitiveness Program for the Electronics Industry and the High Technology Program. In this sense, the 2017 Competitiveness Program sets important goals and strategies for increasing the sector's dynamism. Some of these goals included transforming the country into one of the world's leading exporters of electronic and computer goods, increase direct employment, encourage local suppliers of electronic and electrical components, metal and plastic parts, and supplementary materials, build the country's own technology, and move from Made in Mexico to Created in Mexico (Herrera et al. 2014).

The export-oriented approach to the Mexican manufacturing industry was consolidated after Mexico signed the NAFTA. Since then, the country has gained a strategic position that has enabled it to profitably negotiate with many European nations and Japan as an emerging growth and development trend. For instance, in the first six months of 2017, the manufacturing industry in Mexico increased by 0.4%. The figure might be somewhat small, yet it implies that 5,079 manufacturing establishments were settled in the country and around 2,570,390 new jobs were created (INEGI 2017b). Additionally, during the same period, the country reported three major sources of revenue: national income, foreign income, and services income, representing $161,077.265 million pesos, $240,909.874 million pesos, and $50 736.822 million pesos, respectively. On the other hand, the export-oriented manufacturing industry represented $28,809.5 million USD (and during the first seven months of 2017, it represented $204,509.8 million USD). The automotive industry alone represented $9,513.2 million USD in July 2017 (and in the first seven months, it represented $70.284.9 million USD) (INEGI 2017c).

3.6 The Manufacturing Industry in Ciudad Juárez and Its Evolution

In 1961, the National Border Program (Programa Nacional Fronterizo, PRONAF) sets the legal foundations for a new urban structure that promoted the country's economic and social growth through bilateral trade agreements. Pronaf had two clear goals: to stimulate tourism in border cities and to improve the environmental conditions of such cities, that is to improve their appearance and infrastructure to reach national and regional prestige standards (PRONAF 1961). To reach these goals, Mexico used federal resources and built two major international bridges, Santa Fe and Córdova, to stimulate the dynamism of Ciudd Juárez.

As mentioned in Gutiérrez Casas (2009), urban and industrial development in Ciudad Juárez can be explained through a series of important events. In 1957, the National Economic Development Committee selected the city as a feasible industrial city to receive economic investment. Also, the government of Ciudad Juárez proposed two major industrial centers, one in the North and the other in the South, both adjacent to the railways. None of the projects saw the light, and the economic development of Ciudad Juárez remained staggered until 1965. The federal government then initiated the Border Industrialization Program (Programa de Industrialización Fronteriza, PIF) to set the economic foundations for the economic development of the city, address the high levels of unemployment, and tackle the decline of cotton cultivation. Also, the PIF served as a response to the demise of the Bracero Program by the US' government in 1964 (Fernández 1981).

In May 1965, thanks to the PIF, manufacturing companies located in Ciudad Juárez became major sources of employment, helped equilibrate the country's trade balance through a greater net contribution of foreign currency, improved industrial integration, increased the country's ability to compete in international markets, improved employee training, and contributed to the transfer of technology across regions (INDEX 2017). As a result, after the PIF was formalized in 1966, Ciudad Juárez built its first industrial park and attracted an important television manufacturer. On March 15, 1971, the Customs Code established industrial manufacturing regulations, and in 1972, these were revised for the first time to extend the system to the whole country. Also, from 1972 to 1998, the Secretariat of Economy regulated how working groups were formed in the export-oriented manufacturing industry. In addition, since 1973, the Department of Statistics has been in charge of capturing, integrating, processing, and disseminating important information on the export-oriented manufacturing industry across Mexican cities and states through the Sub-directorate of Economics and Statistics and the Department of Industry (INDEX 2017).

Since such times of industrial prosperity, many public institutions have been established to enforce new industrial laws and regulations and create a positive developmental environment for Mexican workers. Such institutions also identify the problems that directly affect the manufacturing industry and improve the communication among manufacturing companies, workers, and industrial partners. Nowadays, these government institutions are the legal and official voice of the manufacturing sector and contribute to the decision making of joint problems (INDEXJuárez 2017). In Ciudad Juárez, these institutions have also nourished the relationship between the manufacturing industry and the Mexican scientific community, which conjugate their efforts to solve regional problems that affect both the economic development and social well-being of the people.

Ciudad Juárez is the largest city in the state of Chihuahua, located in northern Mexico. It is the second most populous border city, after Tijuana, Baja California (INEGI 2016). Also, Ciudad Juárez has a growing industrial center made up in large part by manufacturing companies, which have contributed to a visible population growth for the last 20 years. Thanks to its economic advantages, the city attracts people from all parts of the country (Cervera 2005) and a great amount of foreign-owned investment (OECD 2010). The city is also favored by its proximity with El Paso, Texas, in terms of employment levels (Avelar-Sosa et al. 2014a) and trade opportunities (Sanchez-Reaza 2010).

3.6.1 The Manufacturing Industry in Ciudad Juárez: Important Data

According to the National Institute of Statistics, Geography, and Informatics, in July 2017, the Mexican manufacturing industry had 528,253 establishments, 121,983 of which were located in Chihuahua and 1,888 in Ciudad Juárez. As for the export-oriented manufacturing industry, it is said to comprise 5,079 establishments in the country, 487 of which are in Chihuahua, and 321 are in Ciudad Juárez. Similarly, in July 2017, the export-oriented manufacturing industry created 2,570,390 national jobs, 378,126 in Chihuahua and 274,615 in Ciudad Juárez. The country's revenue from national trade, goods supply, and services reached $161,077.265 million pesos, and Chihuahua contributed with $2,017.994 million pesos, whereas Ciudad Juárez contributed with $360.886 million pesos. On the other hand, the country's international revenue reached $240,909.874 million pesos. Chihuahua contributed with $15,742.284 million pesos, and Ciudad Juárez contributed with $9,322.977 million pesos (INEGI 2017a). These figures show the important contributions of Ciudad Juárez to the country's economic development, yet they are not definite. The figures are only a point of reference to highlight the importance of conducting research in the export-oriented manufacturing industry of Mexico as a way to promote changes from the inside out.

3.7 Competitiveness in the Manufacturing Industry

In today's globalized world, competitiveness is everything. It brings wealth, promotes economic development, creates jobs, and improves life quality (Herrera et al. 2014). Many economists agree on the claim that the manufacturing industry is one of the key elements of productivity and economic development and has important implications in the other industries. As discussed in Chap. 1, this book addresses competitiveness from a microeconomic level (i.e., corporate competitiveness) to a macroeconomic level (i.e., global competitiveness) that influences the competitiveness of a nation, considering at first the performance of the manufacturing industry and its relationships with international competitiveness).

According to Laos (2000), corporate competitiveness is "the ability of companies to sell more products/services and maintain or increase their market share without sacrificing resources. For a company to be competitive, the market wherein it participates must be open and reasonably competed." Similarly, Laos (2000) claims that competitiveness is not simple. Being competitive is not only about achieving adequate market participation through a series of events that benefit the firm, but it is also about the company's ability to maintain, as much as possible, increasing market participation in a sustainable and continuous manner.

Competitiveness at the corporate or microeconomic level has an influence on costs, use of resources, price, quality, and product differentiation (Herrera et al. 2014; Laos 2000). First, the costs of inputs and raw materials are important, since they largely determine unit costs and therefore the company's profitability and ability to penetrate the desired market. Second, price, quality, and product differentiation affect competitiveness, because a competitive position is usually achieved through high-quality standards and appropriate marketing and distribution channels, that is through truly specialized processes that enable the company to increase its value added and profitability levels (Laos 2000). Competitive firms are usually technologically advanced and build their own technological resources. Similarly, they are certified in diverse aspects and standardize their processes. On the other hand, adequate marketing and distribution channels refer to the way companies manage to put their products in the customer's hands, and they usually include delivery times, customer services, after-sales services, and qualified sales staff, to name but a few.

Competitiveness in export-oriented companies refers to the organization's ability to channel increasing export volumes toward international markets. In this sense, it is important to take into account factors such as demand structure and dynamism, supply structure and dynamism, production performance, and market regulations (Herrera et al. 2014). To understand the first factor, one must realize that competitiveness will depend on the degree to which there is high demand of a given product or service. On the other hand, the second factor refers to the company's ability to keep high levels of investment and to constantly incorporate new technology; moreover, it is important to quantify the level of market penetration from other countries, the level of competitiveness, the nature of the internal market's structure, the relationship between the industry and suppliers, the level of concentration or the geographical distribution of production activities, and the availability of the natural and human resources available.

To be able to compete, companies must interact in a legal physical and regulated environment that contributes to reducing costs and increasing productivity. A company can be the most productive and technologically competitive internally, but if external conditions impose it diverse costs, the competitiveness of this company is actually limited (Herrera et al. 2014). Productivity changes are both a cause and a consequence of the dynamic forces behind the economy: technological progress, accumulation of physical and human capital, companies, and institutional agreements. Consequently, companies should be the starting point in the debate about competitiveness (Abdel Musik and Romo Murillo 2004). Companies as basic economic agents directly respond to the competitive environment by perfecting their production capabilities. Therefore, competition laws and regulations ought to prioritize companies. Productivity is not the only key aspect of competitiveness; there are other external factors and indicators that form the competitive system and contribute to a clear and more comprehensive explanation of how companies can become competitive (Garduño et al. 2013).

Corporate competitiveness is based on specific advantages, such as market share and profitability, which reveal a company's level of competitiveness and ability to survive in the market. The international perspective to competitiveness views companies as the main international market agents and determines a country's level of competitiveness based on that of its companies (Pérez-Escatel and Pérez Veyna 2009). The simple idea in Porter's diamond model is that competitiveness is neither inherited, nor it depends on the economic situation. Instead, competitiveness is achieved through hard work and initiative.

For the last 30 years, the Mexican manufacturing industry has been an essential factor for the country's economic development and direction. Export-oriented manufacturing companies greatly contribute to the country's GDP, and approximately 90% of the manufactured products are exported to the USA. In this sense, as Sobrino (2005) claims, the competitiveness of a country depends on its microeconomic efficiency, economic policies, and the ability of its major cities to attract foreign investment that creates jobs and contribute to local economic growth. Mexico can reach higher competitive levels through its major cities, which would attract foreign investment to initiate new projects with the sole purpose of expanding their market and promoting growth at all levels.

Evaluating competitiveness in manufacturing companies involves identifying those indicators that influence most on their profitability and understanding that being competitive does not only depend on the ability to increase productivity, efficiency, or product quality, but also on externalities related to transportation costs, infrastructure, use of information technology, and government and institutional support. All these elements should be assessed to make sure companies have more effective and efficient activities. In this sense, many studies have been conducted across a wide range of companies—small-, medium-, and large-sized—to find better ways for companies to operate in the dynamic and globalized production environment and satisfy the demand. For instance, López Torres et al. (2012) proposed a competitiveness model for export-oriented manufacturing companies. The researchers suggest that social responsibility and human factors improve employee life quality and thus guarantee greater productivity, quality, and human development. In turn, such benefits impact on company profitability. On the other hand, Sanchez and Silva (2014) conducted a research study in a medical company to analyze the effects of manager–customer and manager–supplier relationships on product quality, being the latter an indicator of competitiveness.

Authors Silva and Magaña (2014) performed a comparative analysis in the light and automotive industries to study the impact of quality certifications on competitiveness. The findings revealed that quality can have effects on corporate profitability and competitiveness. On the other hand, Valencia et al. (2017) used structural equation modeling to analyze their relationship between competitiveness variables and indicators in avocado exporting companies. As main findings, the researchers claim that quality, price, use of technology, and employee training have a strong impact on the levels of competitiveness in this industry. From a slightly different perspective, Garza et al. (2017) analyzed the relationship between segmentation and product innovation strategies and competitiveness in export-oriented manufacturing companies. The researchers found that, in order to improve market positioning, companies must implement merger and acquisition strategies, and to innovate products, they must invest in research and development activities and reduce costs.

As regards the role of external factors, Avelar-Sosa et al. (2014b) studied the effects of the regional infrastructure and offered services on supply chain performance in exporting manufacturing companies. As main findings, the researchers reported important industrial implications, since government policies are a key competitiveness enabler in any country or region. Considering infrastructure-related factors, such as capital and land, countries can compete with one another through basic resources, such as infrastructure, market efficiency, qualified labor force, and ability to use the existing technology; however, global manufacturing networks also depend on what countries can offer, not only on production costs. In this sense, countries become a competitiveness enabler for the companies settled in their territories.

In conclusion, competitiveness in exporting manufacturers is a hot topic for scholars and industrialists alike in their pursuit of the best recipe for higher profitability within an uncertain and dynamic competitive environment. However, the legal and government institutions that nowadays regulate the economies also have an important role in the implementation of long-term economic development projects that provide not only long-lasting competitive strategies, but also ways to systematically improve these strategies, thereby reinventing their ability to enter complex global value chains successfully. The competitiveness of exporting companies in Mexico largely depends on the global value chains in which these companies participate. That said, these companies must comply with specific tasks, forms of work, basic knowledge requirements, experience, abilities, and skills (including foreign language skills) to produce better products at lower costs and with timely deliveries. This allows them to move from a regionally competitive industry to an internationally competitive sector.

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Chapter 4
Supply Chain Evaluation in the Manufacturing Industry

4.1 The Supply Chain

4.1.1 Overview

One of the main goals of companies is to increase efficiency at the lowest possible costs without compromising quality and customer service. International competitiveness has encouraged companies to seek and build cross-border and transatlantic relationships with suppliers and customer through integrated systems and mechanisms. In the end, such relationships should benefit all sides and ensure that businesses can exchange the necessary information, knowledge, resources, and raw materials, to mention but a few. This is where the supply chain assumes a key role in competitiveness. On the one hand, supply chains seek to optimize resources—both domestic and foreign—and increase business profitability through process efficiency along the chain without compromising quality, customer services, and the environment.

The importance of the supply chain lies it is the ability to align with a strategic corporate plan. Production chains must comprise all the links of the economic process, from raw materials to product distribution, since all these links add value to the final product, good, or service. From this perspective, added value is the quality added to the product, good, or service at each stage of its production (D'Alessio 2012).

A supply chain can be defined as a group of three or more companies directly linked through a system of people, activities, information, and resources moving a product or service from supplier to customer (Qi et al. 2017). A supply chain comprises all the members directly and indirectly involved in fulfilling customer needs, from suppliers and manufacturers to carriers, stockists, retailers, and even customers (Chopra et al. 2013). Customers are an essential link of the supply chain, since they set the needs to be covered by the product or service. All the production process and supply chain links exist because of this, and through them, companies

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seek to cover the requirements of the customer while simultaneously making profits. Implicitly, a successful supply chain improves many aspects, including production operations, system productivity, customer service, and commercial relationships with customers and suppliers, all this while helping companies make profits (Blanchard 2010).

Supply chain partners or links perform tasks such as product design, raw material procurement, materials handling, product manufacturing, product distribution, and after-sales service (Su and Yang 2010b). To Stadtler (2005), a supply chain integrates multiple organizations through coordinated upstream and downstream flows of materials, information, and finances in such a way as to satisfy customer needs. On the other hand, Blanchard (2010) defines the supply chain as the sequence of events that cover the lifecycle of a product or service, from its conception to its consumption. A supply chain is responsible for procuring the necessary materials, transforming such materials into intermediary and final products and services, and distributing these products and services to customers. In this sense, the supply chain comprises three major stages: supply, production, and distribution. The first stage analyzes and manages raw material procurement, whereas the second stage refers to the operational activities that transform the procured raw materials into goods. Finally, the third stage refers to redesigning, looking for, and managing delivery activities; however, the distribution stage involves not only finding the most appropriate transportation companies, but also looking for new distribution networks to reduce delivery times and logistics costs. It is a whole strategy.

Some authors such as Lambert et al. (2005) conceive the supply chain as the set of actors, from suppliers to customers, committed to the flows of products, services, finances, and information. Similarly, to these authors, the supply chain must be multidimensional and multidisciplinary, and its design should enable it to react and respond to unpredictable events and improve accordingly (López and Guaderrama 2016). A supply chain is a series of complex exchange processes established both inside of the company and outside of it, with its suppliers and customers (Pulido 2014). The Council of Supply Chain Management Professionals (CSCMP) argues that a supply chain links many companies, initiating with raw materials and ending with the final customer using the finished product, where all suppliers and all customers are connected through customer demands, as well as through the exchange of information and materials in the logistics process (CSCMP 2014). Consequently, we should understand that, internally, in all companies, the supply chain connects the entire organization, especially in terms of commercial functions (marketing, sales, customer service), raw material supply (supply), production (production management, manufacturing), and product storage and distribution (distribution), in order to align internal operations with customer service, time cycle reduction, and capital minimization (Pulido 2014).

To contribute to our understanding of a supply chain, Fig. 4.1 depicts its five main stages interconnected through constant and bidirectional flows of products, information, and money. These flows can be managed through the same stages or by intermediaries. The goal of the supply chain is to maximize the value added in a

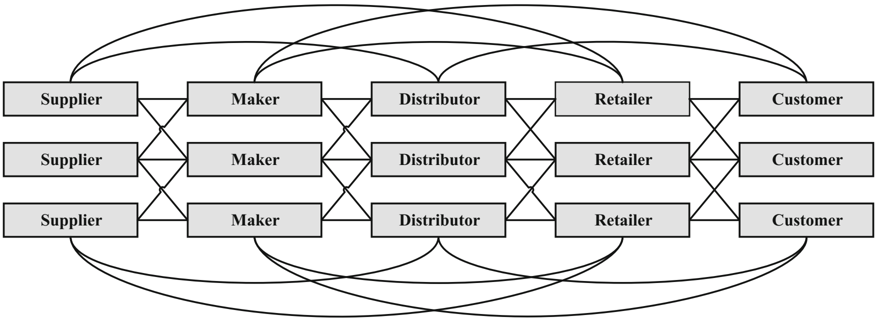

Fig. 4.1 Supply chain stages. *Source* Chopra et al. (2013)

product at each stage of its production, which implies a surplus that is calculated as the difference between customer value and supply chain cost. Suppliers provide manufacturers the necessary raw materials; manufacturers (or makers) transform these materials into final products; and distributors distribute the products to customers, both retailers and end users (López 2014).

Product flow or materials flow refers to the physical movement of goods (Coyle et al. 2013), whereas financial flow is the incomings and outgoings of money along the supply chain; it is the management of working capital. Finally, information flow is the transfer of information across supply chain members, such as orders, billing, and demand forecast. It facilitates the physical flow of products and decision making and can occur in many forms (e.g., virtual, via telephone, written, oral) (Coyle et al. 2013; López 2014). Increasing supply chain efficiency allows companies to reduce costs, increase quality, and streamline operations. In this sense, supply chain management includes the planning and active management of all the activities involved in the procurement and transformation of raw materials. Also, supply chain management involves coordinating and collaborating with the other supply chain partners (Sukati et al. 2012). To Pulido (2014), supply chain management refers to a systematic and strategic coordination between traditional business functions and the tactics of these functions in a particular company. Also, supply chain management manages relationships across supply chain partners, from end users to suppliers, using key multifunctional business processes to create value for both customers and shareholders (Lambert 2014).

Visualizing supply chain management as a process implies identifying three essential stages: customer relationship management (CRM), internal supply chain management (ISCM), and supplier relationship management (SRM). In this sense, Fig. 4.2 depicts this approach. CRM focuses on managing a company's interaction with current and potential customers, whereas ISCM refers to the practice and process for managing internal business functions, and SRM is a comprehensive approach to managing interactions between a company and those organizations that supply the goods and services it uses. The goal of CRM is to generate demand and place and track orders; it includes processes such as marketing, pricing, sales, and

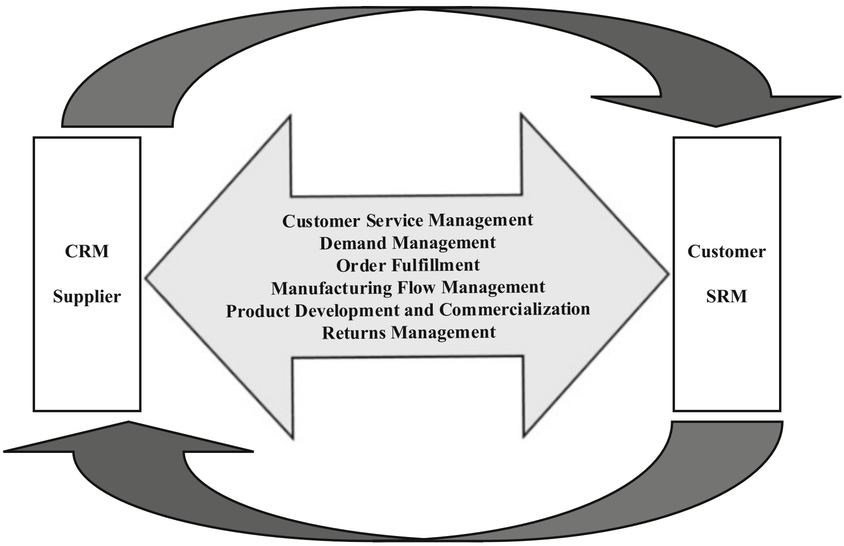

Fig. 4.2 Relationship between CRM and SRM. *Source* Lambert (2014)

order management, to name but a few. On the other hand, ISCM seeks to meet the demand in a timely manner at the lowest possible cost. It comprises aspects such as production planning, supply–demand plan preparation, managing storage capacity, and real order supply. Finally, SRM focuses on sharing demand plans, managing supply sources, supplier selection and evaluation, supply negotiations, and material replenishment orders (Chopra et al. 2013). In addition to depict the aforementioned supply chain management stages, Fig. 4.2 shows the flows of materials and information in the supply chain, as well as the supply chain management strategies for product demand, manufacturing, marketing, product development, customer service, and after-sales services (returns).

Supply chain management implies the set of activities related to the flow and transformation of goods, from raw materials to end products, as well as the related information or financial flows, all of them integrally managed in order to gain a competitive advantage (Ballou 2004). Figure 4.3 provides an example of supply chain management that incorporates activities that make the term supply chain management a comprehensive concept. The structure of supply chain management in this figure has coordination between companies at the top, as it is a key element to both obtain the desired benefits and meet customer demands. This approach also takes into account the coordination between company functions as a way to increase productivity from an individual point of view of the supply chain, that is, coordination from the inside out. In other words, the supply chain management approach illustrated below has two goals. The first is to minimize global costs at the same time companies create value for both customers and shareholders through products delivered in a timely, orderly, and sustainable manner (Ko et al. 2010; Seuring

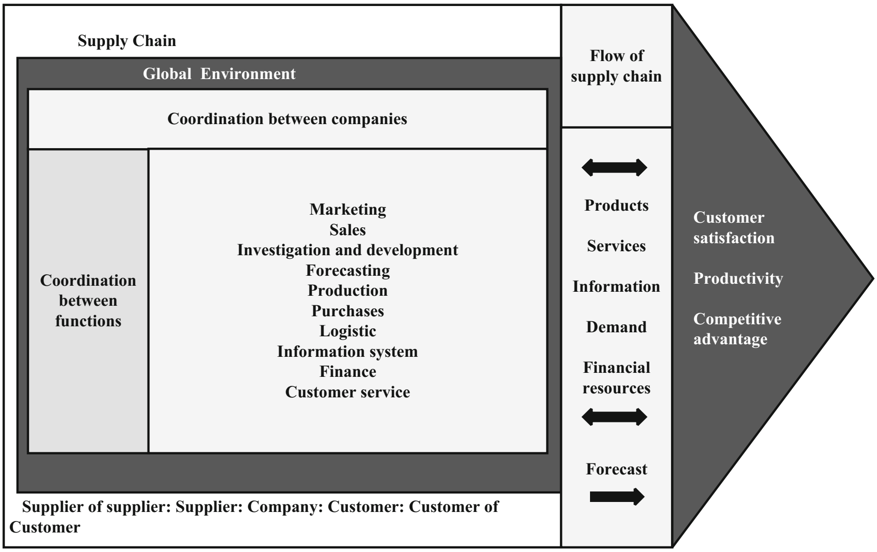

Fig. 4.3 Supply chain management. *Source* Ballou (2004), Mentzer et al. (2001)

2013). The second is to synchronize supply chain member functions to coordinate material and information flows with customer demand. Overall, Fig. 4.3 provides a system-based approach to supply chain management.

4.1.2 Modern Supply Chains

In such an increasingly competitive environment, companies are in the constant pursuit of the best competitive strategies that would enable them to make a difference and increase profits. Some factors that companies prioritize when looking for a competitive advantage are quality, costs, delivery times, and demand response capacity. In terms of quality, companies expect to be recognized by customers as the ones with the highest quality and those whose products are worth their price. Similarly, costs minimization is perhaps the most important competitive strategy whose goal is to have lower production costs than competitors, which means selling at low prices and gaining market share. As for product deliveries, companies commit not only to orderly and timely deliveries, but also to a faster product distribution with respect to competitors Finally, demand response capabilities refer to a firm's ability to cope with changes in customer demands in terms of quantity, design, or competition (López 2014).

Environmental strategies are gaining increasing importance as competitive strategies thanks to the growing level of awareness regarding environmental problems. From this perspective, modern companies seek to comply with the necessary environmental laws and regulations, especially in developed counties. Green production processes seek to systematically avoid and eliminate the volume and toxicity of waste materials and to make the most of the resources through recycling and reusing. Here lies the prestige of the real environmentally responsible corporations, also known as green companies (Büyüközkan and Çifçi 2012; Rameshwar et al. 2017; Sari 2017).

Competitive strategies might seem simple, but in reality, they are a challenge. Globalization and the consolidation of supply chains have increased the complexity of production regimes and trade relationships. Products now have more parts and detailed components, both suppliers and customers are anywhere in the world, and trade regulations and requirements are increasingly delicate and demanding. Therefore, in the greatest extent possible, organizations need to simplify some supply chain aspects, thereby relocating or reducing suppliers, simplifying processes, using information technologies, increasing collaboration and coordination, and using joint performance measurements (Coyle et al. 2013). Undoubtedly, these activities are challenges that companies need to overcome to obtain the benefits that they want.

Companies design their supply chains and set their priorities by considering two things: efficiency and efficacy. Supply chain efficiency focuses on reducing inventory at each stage the supply chain through supplier and manufacturer efficiency. In other words, the goal is to use the least amount of resources at each stage and consequently to minimize costs. On the other hand, supply chain effectiveness refers to the ability to react quickly to changes in demand. Here, inventories are only used to avoid running out of stock, so suppliers must be flexible in terms of raw material delivery (López 2014).

To improve supply chain performance, experts have also taken into consideration risk management, which is the identification, assessment, and control of potential threats to a company's assets. Risks emerge in material and information flow as a result of unfortunate or unforeseen events, such as economic crises and natural catastrophes, and because of modern conditions, such as globalization, market dynamism, and modern supply chains. Unfortunately, risks interrupt the flow and coordination between the demand and suppliers both inside and outside of the production processes (Kainuma 2018; Tang and Tomlin 2008; Tang and Nurmaya Musa 2011). Generally, risks cause poor supply chain performance and therefore affect inventory costs, delivery times, flexibility, supplier responsiveness, and even customer trust (Avelar-Sosa et al. 2014a).

Successful supply chains deliver products in a timely and orderly manner at the lowest possible costs. Therefore, to company managers, increasing supply chain efficiency is the best way to combine the best business strategies and the world's best technology in order to improve internal activities and increase earnings.

Global supply chains that emerged in developed countries have greatly influenced businesses around the world. However, because of their complexity, these supply chains are very difficult to manage. It is hard to imagine all the processes that daily products, from a regular tomato sauce to an iPhone or iPad, undergo until they reach our hands as end products, even though we know that many people, materials, and resources were involved (Pulido 2014). It is also hard to imagine that the ingredients of that store-bought tomato sauce might come from Mexico, Brazil, Argentina, or South Africa, or that the iPhone or iPad has been assembled in Malaysia or China. This complexity is what supply chain management means: managing all the activities that enable the flow of goods and services at each stage of their production and distribution. A failure at some point in the chain affects earlier and subsequent stages, and thus interrupts the flow of materials and information. Therefore, there must be full coordination among SC members, who must not underestimate the power of collaboration, trust, commitment, and synchrony.

Supply chains are important because companies need techniques, methods, and approaches to obtain the benefits they want and thus become globally competitive and accepted. Nowadays, competitiveness is not only about products, but also about supply chains (Feng 2012; Yang 2014). Companies that outstand in international markets have made important modifications to their processes, and perhaps, they have also challenged the ways these processes are traditionally managed. The decisions made inside each company are vital for improving competitiveness levels, since appropriate supply chain management increases supply chain competitiveness and guarantees the survival of companies as businesses (Gunasekaran et al. 2001; Jiménez et al. 2010, 2017).

In conclusion, the literature presented in this section evidences the importance of both supply chain and supply chain management. Each supply chain member or company adapts to the chain according to its needs, functions, and particular goals; however, the key to a well-integrated supply chain is always the careful and efficient management of all its activities. As previously mentioned, a failure at any stage in the chain affects earlier and subsequent stages and consequently compromises system performance and benefits. Nowadays, supply chains are a competitive differentiator, which is why all its stages must be carefully managed.

4.2 Supply Chain in the Export-Oriented Manufacturing Industry

4.2.1 Overview

When Mexico joined industrial and market globalization, its economy became dependent on international markets via the country's involvement in global value chains. Even today, Mexico continues to attract the attention of numerous international companies thanks to the many advantages the country has to offer, such as its geographical location and its participation in many trade agreements that facilitate the entrance to the most important markets worldwide. Similarly, Mexico offers highly qualified and specialized workforce (Juárez and Brid 2016; Manyika 2012). As an emerging market, Mexico is appealing to any company that seeks to increase its participation in international markets. Mexico has managed to develop an important supply chain in industries that are strategic to its economy, such as the automotive and the aerospace industries; as a result, the country has become a key node in the supply chain of international goods and services (Ramírez 2016b).

Supply chains in Mexico evolve thanks to factors such as strategic business models, customer-centered distribution networks, air traffic control, and talent training that companies implement and use holistically and comprehensively (Aragonez 2015). Boons et al. (2012) affirm that production chain networks involve companies, customers, and government and non-government institutions alike, and all of them affect the operational and strategic decisions of companies. Similarly, the authors claim that value chains are connections or links among multiple economic actors, jointly organized to increase productivity and their value added, thereby generating more benefits and higher competitiveness for all. Value chains follow a comprehensive approach, as different social actors can take part in them, including the government, companies, scholars, and non-government institutions (Codespa 2010; Medina et al. 2017).

Modern companies do not compete as individual entities but rather as supply chain partners (Yang 2014). Each supply chain works according to the changes in the market and the maturity of the products; similarly, it evolves as it modifies its capacities (Parmigiani et al. 2011). The competitiveness of a given supply chain depends on the ability of its partners to adapt to sudden and dynamic market changes (Monge and Guaderrama 2016). Because companies know that increasing their individual efficiency is not enough to remain competitive, they are committed to increase that of the supply chain (Li et al. 2006) by aligning their suppliers with their customer; in other words, they optimize their activities to increase profits (Lin et al. 2006). Alignment strategies are not simple, since the larger the supply chain, the more complex the processes. That said, complex supply chains are more prone to interruptions in the flows of materials and information, and because supply chains are a whole system, any failure at any stage and in any company compromises the work of the subsequent stages and supply chain members.

Because of globalization challenges and increasing business complexity, many modern companies are now a part of global supply chains, which forces them to improve their organizational structure, production processes, information systems, human resources, and technologies (Sosa et al. 2012). Export-oriented manufacturing companies in Mexico maintain a close relationship with global supply chains in terms of organizational structure. As this these companies evolve, they directly affect how the business is managed and demand being updated to reach the same goals as international corporations. With such implications, the supply chain in the export-oriented manufacturing industry of Mexico is an important way of making businesses in the country, since it has adopted the management practices of big multinational corporations, thereby becoming fourth-generation companies.

4.2.2 The Supply Chain in the Export-Oriented Manufacturing Industry

From a business perspective, the export-oriented manufacturing industry refers to companies that send goods or services produced one the country to another country. Export-oriented manufacturing companies in Mexico share some common traits but their universe is somewhat heterogeneous in terms of products, capital intensity, labor intensity, technological capabilities, size, location, country of origin, and industrial sector, to name but a few. For this reason, it has been difficult to propose a typology to classify all the export-oriented manufacturing companies (Carrillo and Gomis 2005; Carrillo and Hualde 1996). That said, they are usually classified into first-generation, second-generation, third-generation, and fourth-generation companies.

First-generation exporting companies have simple production processes, such as part assembling, mainly use low-skilled labor, and are usually productively disconnected from the national industry. On the other hand, second-generation companies operate with more complex processes, so they use higher-skilled labor and rely on an incipient supply network with local providers. Third-generation companies involve value chain links with higher knowledge, especially in areas of research and product design, product development, and process development. They form industrial and productive clusters with technical centers, assembly plants, and component and service supplier. Third-generation companies have higher technological capabilities due to complex machinery and electronic systems used to design the prototypes. Also, they have certain degree of free decision making, although customers made the final decisions (García Moreno 2014; Hualde Alfaro 2008). Finally, fourth-generation exporting companies perform functions of parent companies; that is, they coordinate a wide range of manufacturing activities, such as production agents and units interconnected across the country and around the world. The coordination stage relies on information technologies to produce algorithms and software systems to support the information flow across companies and the management of the supply chain.

Coordination is the focus of fourth-generation exporting companies (Carrillo and Lara 2003). For instance, Delphi's Technical Center in Ciudad Juárez is no longer a research and development center as such; it has become a coordination center of many Delphi's operations in Mexico. The center coordinates manufacturing plants throughout the country, research, development and design divisions, customer service, direct and indirect suppliers, and some transportation services, to name but a few. Additionally, Delphi's Technical Center in Ciudad Juárez performs functions such as finances, e-commerce (*B2B*: Business to Business, *B2C*: Business to Consumer), infrastructure development, and information technologies. Finally, it coordinates Delphi's intellectual services (design, conception, algorithms, industrial genie, etc.) (Carrillo and Lara 2003).

Seeing a supply chain as something static and unchanging is impossible, especially in the export-oriented manufacturing industry. Undoubtedly, international businesses have undergone tremendous changes in their search for competitiveness, and such changes have brought new forms of seeing and managing supply chains. In this sense, export-oriented manufacturing companies have complex organizational structures, since they belong to global supply chains that force them to change and evolve from the inside out to improve each functional stage of the chain, thereby contributing to a market differentiation process. Nowadays, third-generation and fourth-generation companies are very common. Because they are associated with global industrial environments, but also with regional policies and national industrial regulations (Carrillo and Gomis 2005), these companies attract a great amount of foreign investment, capital, technology, and training (Fierro 2017; Ollivier Fierro and Thompson Gutiérrez 2009); therefore, they contribute to a better supply chain performance. This supply chain is led by multinational corporations that have managed to deregulate production to end the transformation process of their goods.

It is important to understand that export-oriented manufacturing companies are not only an industrialization model, but also competing organizations with their own lifecycles, strategic operations, and differentiated trajectories that are a part of local and regional production ecosystems (Carrillo 2014). Besides performing increasingly complex production processes, export-oriented manufacturing companies have high technology and can modify their production processes in versatile manner by increasing or decreasing production, changing models, substituting products, incorporating innovation, and obtaining international certifications. As time goes by, these companies perform more and more product design and engineering activities and are often acknowledged for their quality, environmental awareness, and safety. As Jorge (2007) points out, foreign companies are "Mexicanized."

Improvement opportunities for exporting companies include integrating efficient management practices, assessing their performance through risk management models, and identifying critical success factors (Barratt and Oke 2007). Such positive initiatives would contribute to efficient and effective supply chains and would demonstrate that Mexico's potential is not only due to its proximity to the USA, but also to its ability to manage complex functions of parent companies. In this sense, Nacash (2016) highlights three important trends to increase the country's competitiveness: flexibility, resilience, and safety. Such trends can have a positive impact on the export-oriented manufacturing industry because of the technological and innovation needs of the global market, thereby making Mexico the fifth world economy by 2050. Other improvement opportunities can derive from strengthening logistics strategies, especially in the automotive industry, which is an important source of economic growth and industrial development. In this sense, industries in Mexico can seek the support of other logistically prepared organizations.

4.3 Supply Chain Evaluation Trends

Current supply chains are generally analyzed and assessed through different approaches with the sole purpose of identifying improvement opportunities in terms of management and coordination among supply chain partners in such a way as to concentrate efforts, improve benefits for all, and expand the relationship of the supply chain with global supply chains. Many studies emphasize the importance of supply chains as competitiveness tools. Supply chains are also viewed as a key element that contributes to the globalization of production operations; at the same time, it increases competitiveness, since companies no longer compete as individual entities, but rather through their supply chains. In this sense, globalization needs strategic improvements (Feng 2012).

Many supply chain aspects or attributes have been evaluated throughout the years in many contexts, from local to international environments, to assess their impact on supply chain performance and competitiveness. In their work, Avelar-Sosa et al. (2014b) conducted a literature review of 95 articles to identify the most common supply chain aspects that have been studied since 2007–2012. In this sense, Table 4.1 presents the most recent findings of this literature review.

As can be observed, several supply chain attributes are studied to propose better forms of supply chain management. In their work, Ranganathan et al. (2011) studied the impact of information networks through a model of four elements. The authors assessed the relationships among these elements to determine their impact on supply chain performance. On the other hand, Ramanathan and Gunasekaran (2014) and De Giovanni and Esposito (2012) studied the impact of collaboration among supply chain members on supply chain performance. In this sense, many other communication and collaboration aspects have been analyzed in other works to assess their impact on supply chain performance (Blome and Schoenherr 2011; Büyüközkan and Çifçi 2012; Navid and Ismaeli 2012; Schotanus et al. 2010). Researchers have also been interested attributes such as supply chain dynamism (Cho et al. 2012; Su and Yang 2010b; Wiengarten et al. 2012), flexibility, and agility. These three attributes are said to be critical to meet the desired levels of customer service (Blome and Schoenherr 2011; Navid and Ismaeli 2012). Also, in their work, Askarany et al. (2010) studied the importance of suppliers and pointed out that supplying processes can be seriously affected by a lack of information and communication. Similarly, Huang et al. (2012) and Blome and Schoenherr (2011), Janvier-James (2012), respectively, analyzed demand and supply as critical elements. Namely, the authors analyzed how wrong demand and supply forecasting have a direct impact on customer satisfaction.

All the works discussed above share a common goal: to make contributions to a better supply chain management to increase benefits and improve customer satisfaction through high-quality and accessible products delivered in a timely, orderly, and sustainable manner. The findings of Avelar-Sosa et al. (2014b) as regards the literature review have certainly changed, and many new attributes are analyzed in supply chain performance. In this sense, the following chapters will present updated

Table 4.1 Supply chain attributes

SC attribute	Author (year)
Agility	Navid and Ismaeli (2012), Blome and Schoenherr (2011), Büyüközkan and Vardaloğlu (2012), Kisperska-Moroń (2011), Ranganathan et al. (2011)
Coordination, collaboration	Schotanus et al. (2010), Singh et al. (2011), Blome and Schoenherr (2011), Büyüközkan and Vardaloğlu (2012), Autry et al. (2010), Navid and Ismaeli (2012)
Information	Ranganathan et al. (2011), Youn et al. (2012), Tanmoy and Craig (2010), Prajogo and Olhager (2012)
Flexibility	Su and Yang (2010a), Wiengarten et al. (2012), Cho et al. (2012), Horatiu and Daniel (2012), Merschmann and Thonemann (2011)
Customer service	Singh et al. (2011), Olugu et al. (2011), Whitten et al. (2012), Cho et al. (2012), Özdemir and Aslan (2011), Kumar et al. (2011)
Processes	Huang et al. (2012), Green et al. (2012), Teller et al. (2012), Elgazzar et al. (2012), Blome and Schoenherr (2011), Papageorgiou (2009), Tanmoy and Craig (2010), Tang and Nurmaya Musa (2011), Janvier-James (2012)
Suppliers	Blome and Schoenherr (2011), Merschmann and Thonemann (2011), Papageorgiou (2009), Persson (2011), Olugu et al. (2011), Whitten et al. (2012), Cho et al. (2012), Jan Stentoft and Teit (2012), Askarany et al. (2010), De Giovanni and Esposito Vinzi (2012)
Demand	Huang et al. (2012)
Costs	Elgazzar et al. (2012), Askarany et al. (2010), Navid and Ismaeli (2012), Cedillo-Campos and Perez-Araos (2010), Horatiu and Daniel (2012), De Giovanni and Esposito Vinzi (2012), Green et al. (2012)
Procurement	Feng (2012), Huang et al. (2012), Janvier-James (2012), Blome and Schoenherr (2011)
Performance	Autry et al. (2010), Cedillo-Campos and Perez-Araos (2010), Cho et al. (2012), Choi (2010), De Giovanni and Esposito Vinzi (2012), Elgazzar et al. (2012), Green et al. (2012), Horatiu and Daniel (2012), Janvier-James (2012), Özdemir and Aslan (2011), Papageorgiou (2009), Persson (2011), Su and Yang (2010b), Tang and Nurmaya Musa (2011), Whitten et al. (2012)

Source Avelar-Sosa et al. (2014b)

references to analyze each supply chain attribute that seems to have an effect on supply chain performance.

Some other common attributes used to evaluate supply chains include costs, planning, production capacity, productivity, commitment, trust, resources, innovation, integration, distribution, quality, and environmental impact. That said, the most commonly studied supply chains belong to the following industries:

– Textile industry
– Chemical industry
– Petrochemical industry
– Food industry

- Automotive industry
- Electronics industry
- Computer products industry
- Services industry
- Manufacturing industry
- Logistics industry
- Communications industry
- Plastics industry
- Medical industry

Some of the most common methodologies to analyze supply chains at different stages include linear discriminant analysis, experiment design, linear regression, empirical and descriptive analyses, analytic hierarchy process (AHP), factor analyses, structural equations, and neuronal networks to name but a few. In any case, researchers look for the best alternative to improve a given aspect of the supply chain (Avelar-Sosa et al. 2014b). After conducting the literature review, we reaffirmed our desire to write this book. Many approaches are proposed to evaluate supply across a wide range of countries and contexts, yet we feel the need to dedicate this book to export-oriented manufacturing industries as a way of contributing to their supply chain management and competitive strategies.

To conclude this section of the chapter, we would like to highlight that large number of methods and techniques for supply chain evaluation are not an obstacle to keep wondering and researching on what makes a supply chain perform better and be more competitive. No matter how small they are, all companies have a fundamental purpose: to make profits by penetrating the market. To this end, each company makes improvements in their businesses by restructuring their processes (lean supply chain management, agile supply chain management), changing their business strategies (e-commerce, business to business), incorporating technologies (ERP: Enterprise Resource Planning, RFID: Radio-Frequency Identification, UPC: Universal Product Code, GPS: Global Positioning System, Internet, etc.), delegating logistic responsibilities (outsourcing, offshoring, cross-docking), and improving relationships with suppliers (CPFR: Collaborative Planning, Forecasting and Replenishment, VMI: Vendor Managed Inventory). As Dinu (2014) points out, the success of a company is due, to a great extent, to their supply chain management techniques, the information and communication technologies they use, the quality of the information that they share, and because of the Internet, to name but a few (Nativi and Lee 2012; Ranganathan et al. 2011; Su and Yang 2010b).

4.4 Supply Chain Evaluation in the Export-Oriented Manufacturing Industry

The studies presented in Table 4.1 have contributed to the study of the supply chain in Mexico across a wide range of companies and regions. Scholars, business people, and industrialists are all equally important for identifying both short- and long-term strategies to build a reference model for economic growth.

To discuss supply chain evaluation approaches in the supply chain of export-oriented manufacturing companies in Mexico, first we need to discuss the particular characteristics of the environment, especially in the case of border cities. In this case, the book focuses on the exporting companies located Ciudad Juárez, in the state of Chihuahua, in northern Mexico. Ciudad Juárez is the largest city in the state of Chihuahua and the second most populous border city, after Tijuana, Baja California (INEGI 2016). Also, Ciudad Juárez is the seat of many export-oriented manufacturing companies that have significantly boosted the city's industrial and social growth for the last 20 years. It is also an attractive place not only for people from the state of Chihuahua, but also for Mexicans from all the country (Cervera 2005). Similarly, Ciudad Juárez is considered a very favorable region for the concentration of manufacturing companies thanks to the economic advantages that the city offers (OECD 2010).

Ciudad Juárez is also a source of employment and economic development thanks to the manufacturing industry that flourishes in the region and because of its proximity to El Paso, Texas (Avelar-Sosa et al. 2014c). Its geographical location and environment allow manufacturing companies to export and import goods easily, reduce process time, and minimize logistic costs (Sanchez-Reaza 2010). Numerous studies have been conducted among manufacturing companies in Ciudad Juárez to contribute to the performance and development of their supply chain. For instance, (Ramírez et al. 2016a) analyzed the relationship between logistic competencies and effective inventory management through inventory reliability and inventory obsolescence costs. Similarly, Contreras et al. (2016) analyzed the effects of incorporating local companies in the global value chain and the impact of knowledge transfer mechanisms in the area of manufacturing and management practices from leading corporations to local firms. From a different perspective, Monge and Guaderrama (2016) studied dynamic capabilities of absorption, innovation, and responsiveness and their effect on supply chain agility.

Researchers (Fernández et al. 2015) explored logistic aspects of the supply chain of the export-oriented manufacturing industry of Ciudad Juárez through a model that measures the impact of national and international logistics and supply logistics on supply chain performance indices. On the other hand, Fernández et al. (2015) discussed green supplier attributes as strategies for generating high-quality green products. Additionally, (Avelar-Sosa et al. 2014c) examined the effects of regional infrastructure and services on supply chain performance, whereas (Loya et al. 2016) studied the role of information and communication technologies in both supply chain agility and corporate benefits. All these works address specific supply chain evaluation methodologies, such as AHP, fuzzy logic, structural equations, descriptive analysis, empirical analysis, and literature review, among others.

The importance of conducting these kinds of studies in the export-oriented manufacturing industry lies in the role of this industry as a key element for increasing productivity and economic growth. In turn, economic growth goes hand in hand with employment opportunities in a given region and the technological progresses. It also contributes to a country's gross domestic product (GDP) and improves life quality. That said, the supply chain is one of the cornerstone of the manufacturing industries. On the one hand, it improves the management of the production system, and on the other hand, it increases collaboration among supply chain members in order to unify goals and make a difference in the market (Reich 2010). Nowadays, dynamic factors such as the complexity of production systems and globalization allow companies to gain the desired economic growth and benefits through appropriate supply chain management. In this sense, companies evaluate their performance, pursue sustainable development, and commit to offering high-quality customer service through an effective supply chain management approach (Ramírez et al. 2016b). Consequently, there is an increasing interest to look for, identify, and assess improvement alternatives in the production process, and such improvement alternatives are the motivation of supply chain studies conducted in the manufacturing industry.

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Part II
Supply Chain Performance Factors

Chapter 5
Conceptualization of Supply Chain Performance

5.1 Supply Chain Performance

5.1.1 Definition of Performance

Because the supply chain is a key aspect of competitiveness, companies have become increasingly committed to evaluating and tracking their performance to prevent failures and unachieved goals. There is a long way to find those evaluable or measurable performance elements that provide feedback and encourage corrective actions in the production chain (Gunasekaran et al. 2004; Gunasekaran and Kobu 2007). That said, managing performance is important, since performance allows the deployment of supply chain strategies that lead the chain to achieve its goals. Also, managing performance increases efficacy, as companies are able to adopt the best internal and external operational strategies without excluding any supply chain partner (Chen and Paulraj 2004).

The supply chain is a complex corporate process that relies on a hierarchical structure of the value added to a product. Achieving a high-performance supply chain design is a challenging task due to this complex value-added structure and current market dynamics. It is difficult to make decisions in large-scale systems, especially in supply chains, with so many hierarchical levels and a massive flow of inputs, operations, and functions.

Performance measurement systems are an integral part of any resource organization processes. For the last 30 years, many companies have invested great amounts of financial capital, time, and effort to develop and implement such systems (Koufteros et al. 2014). Measuring supply chain performance can help better understand how it works and can improve its performance by comparing current with past performance or future performance trends. Consequently, all supply chain members, that is companies, partners, and collaborators, have the obligation to generate performance metrics. As previously mentioned, the interest in performance measurement has increased markedly (Paolo et al. 2010) and performance

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measurement systems are now considered as a crucial element for improving supply chain performance (Kurien and Qureshi 2011), especially because they help companies better understand and satisfy their customers' needs while simultaneously keeping low costs. Also, measuring performance is a comprehensive evaluation of supply chain management and provides favorable conditions to improve it.

Performance measurement is simply a critical process that quantifies efficiency (adequate use of resources in order to satisfy customer needs) and effectiveness (degree to which customer needs are appropriately met) in a given activity (Gunasekaran and Kobu 2007). Similarly, performance measurement identifies success or failure and therefore detects specific process problems to be timely resolved. Likewise, performance measurement should be able to integrate all functional areas and call on all supply chain members to evaluate the obtained performance results. Additionally, supply chain performance measurement sets starting points to reconfigure organizational and strategic goals to increase market differentiation and penetration through competitiveness; also, it improves both supply chain efficiency and effectiveness. In conclusion, performance measurement can be defined as "*a set of metrics used to quantify the efficiency and effectiveness of supply chain processes and relationships, spanning multiple organizational functions and multiple firms and enabling supply chain orchestration*" (Maestrini et al. 2017).

5.1.2 Goal of Performance Measurement

The first thing to do to measure the performance of supply chain is to define the goals of the evaluation. For instance, a basic definition describes supply chain performance as the ability of a supply chain to provide timely, orderly, and high-quality products, minimize production costs, and improve customer services (Whitten et al. 2012). Also, supply chain performance is viewed as the ability of the chain to deliver products in the right place, at an agreed time at the best possible logistics costs (Zhang and Okoroafo 2015). To other researchers, it is the degree to which a supply chain meets end-customer requirements at any time and at the lowest possible costs (Ortiz and Jiménez 2017). As a summary, supply chain performance is the ability of any supply chain to understand customer needs, associated with product availability, on-time deliveries, and adequate inventory levels.

The main purpose of measuring supply chain performance is to obtain useful information for managers (i.e., senior managers) and know how efficient the whole system is at a particular time. Similarly, supply chain measurement supports strategic planning and goal setting (Ilkka 2015) and shows how the supply system works by giving follow up to indicators and metrics. Without the ability to measure and track the evolution of supply chain performance, the process of developing strategic plans and goals is less significant. Measuring performance improves internal responsibility and provides decision makers an important tool for increasing responsibility across supply chain members. Employees from all hierarchical levels report their performance to their supervisors, who in turn are held accountable by senior managers. Measuring performance is an appropriate tool for managing business processes.

5.1.3 Performance Indicators

A good performance measurement system relies on carefully and appropriately selected indicators, which is usually a challenge in many companies. Consequently, supply chain management has become a long and complex but also key process to track performance indicators at each supply chain stage. In this sense, Estampe (2014) suggests three main performance evaluation criteria: efficacy, efficiency, and effectiveness. Efficacy is the relationship between the outcomes achieved and the goals set, whereas efficiency is the relationship between the efforts and resources expended in an activity and the value of the profits as a result of this activity. Finally, effectiveness is the relationship between outcome and satisfaction. This approach undoubtedly comprises most of the existing performance indicators, since this is based on hierarchical, strategic, tactical, and operational levels. On the other hand, performance also involves organizational functions such as production, distribution, marketing, sales, and research and development (Leończuk 2016). These supply chain functions must be constantly improved, not only from a global point of view but also from an individual approach, that is, inside each company.

5.1.4 Performance Improvement Goals in the Supply Chain

As previously mentioned, supply chain performance measurement shows how well the supply chain is managed and whether the outcomes have been attained according to the company's strategies. In this sense, when companies measure performance, they pursue specific goals that, if clear, facilitate performance evaluation. Some of the fundamental goals of supply chain performance measurement systems as reported in the literature can be stated as follows:

To researchers Akyuz and Erkan (2010), the purposes of supply chain performance systems are:

- Identify success
- Identify if customer needs are met
- Better understand processes
- Identify bottlenecks, waste, problems, and improvement opportunities
- Provide factual decisions
- Enable progress
- Track progress
- Facilitate a more open and transparent communication and cooperation

To other authors, supply chain performance systems must have the following attributes (Gunasekaran et al. 2001; Gomes et al. 2004; Thakkar et al. 2009; Tangen 2005; Kurien and Qureshi 2011):

– Be simple and easy to use
– Have a clear purpose
– Provide rapid feedback
– Identify improvement opportunities, not only supervise performance
– Reinforce corporate strategies
– Consider both short- and long-term corporate objectives
– Be consistent with the organizational culture
– Do not be in conflict with each other
– Enter both horizontal and vertical organizational structures
– Be coherent with the acknowledgment and reward system of the company
– Focus on what is important to customers
– Focus on what competitors are doing
– Identify and eliminate waste
– Boost organizational learning

Performance measurement is a vital strategy that diagnoses control mechanisms to measure the results of the current supply chain management approach (Wouters 2009). To authors Gunasekaran and Kobu (2007), supply chain performance measurement is valuable and suggests the following purposes of performance measurement systems:

– Identify success
– Identify if customer needs are met
– Better understand processes
– Identify bottlenecks, waste, problems, and improvement opportunities
– Provide factual decisions
– Enable progress
– Track progress
– Facilitate a more open and transparent communication and cooperation

Note that all the authors agree on three fundamental goals of performance measurement systems: identify success, be consistent with corporate strategies, and ensure communication among all supply chain members. Moreover, in every case, supply chain performance measurement systems must consider decision making from a comprehensive approach. In this sense, corporate goals must be aligned with such performance measurement systems to perform objective measurements and congruent results. The following section comments on the evolution of the concept of supply chain performance to complement its conceptualization and highlight the importance of an appropriate supply chain measurement.

5.1.5 Evolution of Supply Chain Performance

To some experts, the evolution of the notion of supply chain performance can be studied through two stages, the first stage comprises from 1880 to the late 1980s, whereas the second one initiated in the late 1980s (Gomes et al. 2004). The first stage focused on quantifying and evaluating operational costs in companies (Kurien and Qureshi 2011) and incorporated a financial performance approach (i.e., profits and return on investment). This is said to be a traditional way to measure performance, and it had some limitations as an approach to comprehensively measure and evaluate business success (Bourne et al. 2003). Consequently, at the second stage, performance is associated with the globalization of business activities and changes in business growth. Gomes et al. (2004) claim that to be consistent with their strategies, companies need to consider both financial and non-financial aspects when measuring supply chain performance.

During the 1980s, businesses started organizing themselves and operating under a global production and customer satisfaction scheme. Then, in 1990, the evolution was so significant thanks to the popularity of automated processes. Eventually, in 2000, the organizational structure of companies radically changed thanks to modern information and communication technologies that were applied to commercial activities; e-commerce emerged, and external economic activities changed. As a result, the supply chain was conceptualized from a global approach (Kurien and Qureshi 2011). In general, the evolution of performance comprises four main stages as described in Gomes et al. (2004) and Morgan (2007). Such stages are summarized in Table 5.1.

As can be observed, before 1980, the goals of performance measurement systems and methods were (1) to determine the profits of systematic large organizations by quantifying total process costs and (2) to promote only efficiency. Ten years later, companies changed their organizational structure and started to see themselves as global businesses, yet performance was still dominated by financial aspects. Also, the notion of value-added became popular, and soon, businesses started realizing about the importance of non-financial aspects. In 1990, the incorporation of automated processes leads to the measurement of performance in production processes and quality under a customer focus. Likewise, companies understood the importance of measuring overall organizational performance and thus adopted a proactive perspective. In the next decade, organizational structures adhered to concepts such as responsibility and integration, and performance was measured and evaluated through internal activities without neglecting the collaboration and cooperation among business partners. Businesses now worked from a balance and comprehensive approach that adopts greater proactivity in order to improve each supply chain stage.

Some other researchers argue that the notion of performance measurement went through two important stages, which are the traditional (past) approach and the innovative (current) approach. For instance, in their work, McCormack et al. (2008)

Table 5.1 Evolution of performance measurement and context organizational

Period	Characteristics of the organizational structure	Characteristics of performance measurement systems
Before 1980	Systematic large organizations	(a) Costs accounting orientation (b) Promote efficiency, facilitate budgeting, and attract external capital (c) Performance measurement based on transaction costs and profit determination
1980–1990	Global business organizations	(a) Costs accounting orientation (b) Value-added perspective
1990–2000	Business process automation	(a) Mixed financial and non-financial orientation (b) Mixed retroactive and proactive approaches (c) Performance measurement includes processes, quality, and a customer focus (d) Results are used to manage the entire organization
2000–2010	E-Commerce and borderless business activities	(a) Balanced and integrated orientation (b) More proactive approach (c) Results used to improve organizational responsiveness (d) Performance measurement enhanced to give a balanced view of the organization and include the supply chain and inter-process activities

Source Gomes et al. 2004, Morgan 2007

performed a comparative analysis on the changes in the notion of performance between these stages or approaches.

Figure 5.1 summarizes the main characteristics of each performance vision. As can be observed, the traditional approach was based on costs and profits and relied on individual and functional metrics. On the other hand, the current or innovative approach to performance is always oriented toward the notion of value, customer, and improvement monitoring, whereas performance metrics are visualized as team and transversal metrics. Similarly, companies now aim at performance evaluation and involvement and seek compatibility of performances, whereas in the traditional vision, companies aimed only at evaluation and sought trade of between performances. In conclusion, this classification of past and current performance vision is clear and forceful and encourages the development of new performance measurement ideas.

From a slightly different perspective, Neely (2005) classifies performance measurement research into five phases, illustrated in Table 5.2. Phase 1 comprises from 1880 to 1990, Phase 2 from 1990 to 1995, Phase 3 from 1996 to 2000, Phase 4 from 2000 to 2005, and Phase 5 from 2005 until now. According to the author, in the first phase, there was a prevailing discussion on the internal problems of performance measurement systems and an evaluation of their operational impact. On the other hand, by 1990, potential solutions were being proposed to address the previously identified problems. Then, in the third phase, the literature mainly discussed ways in which the proposed frameworks and methodologies could be used.

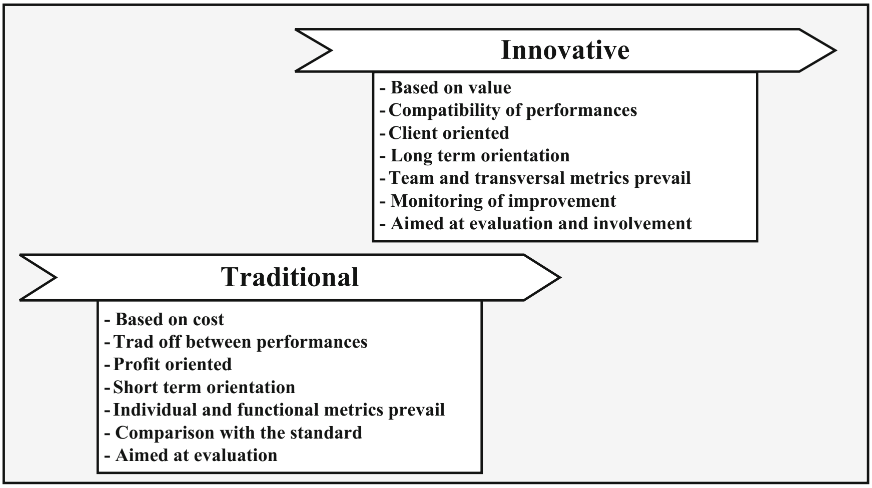

Fig. 5.1 Characteristics of traditional and innovative performance vision

Table 5.2 Evolution of performance measurement vision

Phase 1 1980–1990	Phase 2 1990–1995	Phase 3 1996–2000	Phase 4 2000–2005	Phase 5 2005–today
Prevailing discussion on the internal problems of performance measurement systems and an evaluation of their operational impact	Potential solutions are proposed to address the previously identified problems	Discussion on ways in which the proposed frameworks and methodologies can be used	Performance measurement frameworks and methodologies of previous phases were restructured and made more robust	Performance is not measured individually in each company, but rather in the supply chain throughout its different stages, where companies are considered as components of a much larger system

Source Neely 2005

Throughout the fourth phase, the performance measurement frameworks and methodologies of previous phases were restructured and made more robust. Finally, in recent years, performance is not measured individually in each company but rather in the supply chain throughout its different stages, where companies are considered as components of a much larger system.

In their work, Bititci et al. (2012) present a review of performance measurement research to identify performance challenges and trends from 1900 until now. The authors study the evolution of performance from a five-stage approach. The identify

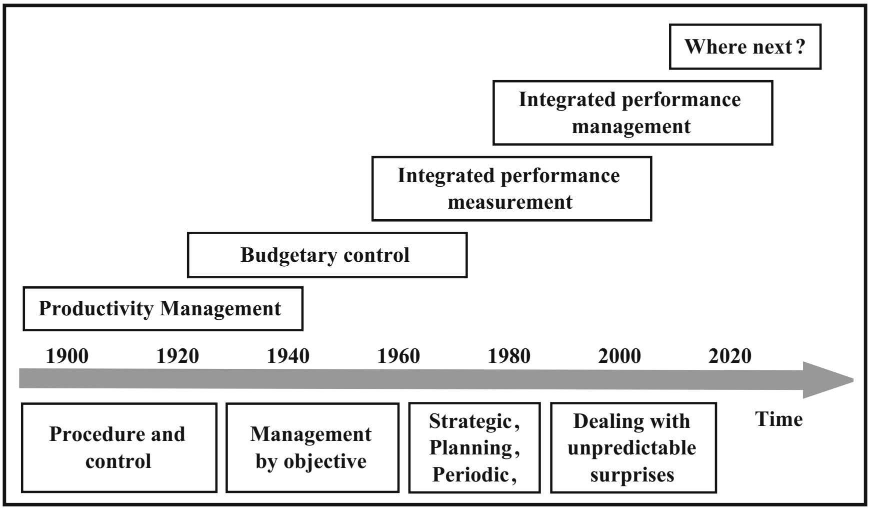

Fig. 5.2 Performance challenges and trends. *Source* Bititci et al. (2012)

stages are (1) 1900–1930; (2) 1940–1970; (3) 1980–1990; (4) 1990–2000; and (5) 2010–2020. These stages are summarized in Fig. 5.2. The horizontal timeline depicts the research scenarios and the upper part of the figure depicts the approaches.

As can be observed, the visions of performance and performance measurement have radically changed throughout the years, especially thanks to the development of more robust methodologies, frameworks, and approaches and because of the evolving structure of supply chains, which have become global and interrelated networks that comprise all types of companies complex flows of information, materials, resources, money, and customers. In this sense, customers are the main and changing supply chain actors that indirectly put pressure on businesses by expecting high-quality products with shorter cycle times but also greater quality and flexibility.

5.2 Supply Chain Performance Attributes (Metrics)

A performance attribute is a group of metrics used to express a competitive advantage (Council 2012) or the ability of the supply chain to deliver high-quality products and services in a timely and orderly manner at the lowest possible costs (Green et al. 2012). These metrics indicate whether the strategic goals provide information and direct feedback about supply chain processes, and are the base to evaluate alternatives and decision criteria (Avelar-Sosa et al. 2014).

Performance can be internally measured when companies monitor and manage their internal processes. This type of performance measurement is known as operational performance measurement, since it focuses on the management of a company's inner operations (Maestrini et al. 2017). That said, another way to measure performance is from the outside through the monitoring and management of inter-corporate processes and supplier–buyer relationships (Luzzini et al. 2014; Melnyk et al. 2014). Many researchers have made important contributions to this matter. For instance, Gunasekaran et al. (2004) proposed six performance measurement metrics from the SCOR model in the context of four supply chain activities/processes—planning, sourcing, making/assembling, and delivering—although other studies suggest five processes—planning, sourcing, making/assembling, delivering, and returning (Theeranuphattana and Tang 2007; Shepherd and Günter 2010). In any way, these aspects measure quantitative and qualitative aspects related to costs, time, quality, flexibility and innovation, responsiveness, and reliability, among others.

In their work, Chan et al. (2003) present an approximation to performance measurement that includes costs and resource utilization, as quantitative measures, and quality, flexibility, visibility, reliability, and innovation as qualitative measures. Overall, performance metrics can be categorized with respect to business processes in terms of strategic, tactical, and operational (Gunasekaran et al. 2004), or with respect to the functional stage where they are being measured (Shepherd and Günter 2011). This will be thoroughly explained in the following subsection to present the wide range of performance attributes on which companies rely today to align their corporate goals and perform their business activities. First, we address quantitative attributes and then qualitative attributes.

5.2.1 Performance and Measurement Categories

As previously mentioned, supply chain performance comprises a set metrics used to evaluate the outcomes achieved through a competitive strategy. Performance can be conceptualized in many ways throughout the different approaches and contributions that so far have been proposed. In this sense, we can talk about quantitative performance and qualitative performance. Quantitative performance is a metric or set of metrics that can be clearly and precisely quantified, mathematically speaking. Quantitative aspects of performance include costs, number of delivered products, and time expended, among others. On the other hand, qualitative performance is conceptualized from an intangible perspective and requires other elements to be quantified or measured. For instance, to measure the quality of a cellphone, it is not enough to consider the brand or the price. It is also important to take into account aspects such as speed, storage capacity, camera features, weight, and resistance, to name but a few. All these aspects describe customer expectations, and therefore, it is not enough to say that a given company meets the product requirements. It is also important to analyze step by step each stage that comprehensively contributes to the quality of a product. In this sense, we can argue that qualitative performance associates not-directly measurable aspects, whereas quantitative performance associates aspects related to costs (sales, total costs, inventory), customers (delivery times, responsiveness, product delay), and productivity (capacity and resource utilization) (Chan et al. 2003).

Performance can also be conceptualized from financial and non-financial perspectives. Financial performance measures the outgoings of a company with respect to the economic goals achieved (Chen and Paulraj 2004), such as sales growth, profitability, and inventory turnover (Merschmann and Thonemann 2011). Cash flow is traditionally used to measure financial aspects, yet other measures are available, such as profit margin and investment turnover. The profit margin ratio measures how much a company keeps in earnings from every dollar of sales it generates, whereas the inventory turnover ratio shows how many times a company's inventory is sold and replaced over a period of time. In this sense, a high inventory turnover ratio implies either strong sales and/or large discounts.

Non-financial performance reflects supply chain operational efficiency in terms of flexibility, agility, and customer service. Flexibility is a key competitive strategy that refers to a company's ability to respond to market uncertainty, including changes in the environment, customer preferences, and competitive forces, among others. Traditionally, studies evaluate organizational performance based on numerous financial indicators, which include important organizational strategies, and non-financial indicators, such as product quality and customer satisfaction (Ranganathan et al. 2011).

Some studies propose performance measurement systems that assess three aspects: resources, outputs, and flexibility. Resources refer to the efficient management of resources, such as manufacturing costs, inventory costs, and return on investment. Meanwhile, output is commonly used to measure aspects such as customer responsiveness, on-time deliveries, and product quality. Finally, flexibility can measure a company's ability to accommodate large volumes of materials and respond to fluctuations in supplier planning. Both flexibility and outputs are non-financial performance measures, whereas resources are a financial performance measure (Wu et al. 2014).

To other studies, reliability, flexibility, quality, and efficiency are the basic supply chain performance indicators (Wu et al. 2014; Angerhofer and Angelides 2006). Reliability measures delivery times with respect to promised prices, whereas flexibility is the degree to which companies can react to uncertainty in the market, new product requirements, and customer exigencies. On the other hand, quality measures how well a product meets customer needs, while efficiency relates process improvement with lower inventory levels, lower manufacturing costs, and higher production volumes. In this case, flexibility, quality, and efficiency are non-financial indicators of supply chain performance, whereas efficiency is a financial indicator.

Authors Wu and Chang (2012) propose profitability and income, organization and human capital, supply chain improvement, and customer relationships as supply chain performance indicators. In this case, profitability and income can be considered as financial indicators of supply chain performance, whereas the remaining aspects are non-financial indicators. Similarly, the authors claim that it is important to take into accounts the individual characteristics, such as company size and type, since these aspects can have significant effects on supply chain performance.

Finally, to authors Gunasekaran et al. (2001), supply chain performance should be measured through the following metrics:

- Forecasting accuracy
- Lead time for delivery
- Product/service variety
- Capacity utilization
- Process cycle time
- Product development time
- Supply chain response time
- Perceived quality
- Transportation costs
- Inventory costs
- Production costs
- Return on investment
- Information handling costs
- Cash flow

Some studies incorporate environmental performance into traditional supply chain performance measurement approaches, thereby associating a company's level of waste with their use of resources (Qinghua et al. 2005). Similarly, other research works study environment management systems as a way to improve supply chain performance (Miroshnychenko et al. 2017; Ramanathan et al. 2017). Environment management is a systematic process that measures and assesses a company's environmental performance. It is important that companies have adequate environmental indicators to obtain reliable and objective information and use this information to transform a company's performance management approach (Chen et al. 2017). Performance is used to measure the level of resource utilization in companies, but environmental performance must be approached from a social perspective. Authors Azfar et al. (2014) analyzed supply chain performance attributes from a review of the literature and classified such attributes into three types of performance as shown in Table 5.3. Note that the authors conceive non-financial performance as operational performance.

Other studies categorize supply chain performance attributes into quantitative performance and qualitative performance, which correspond to the previously discussed financial and non-financial performance. For instance, Chan (2003) developed a reference framework to measure performance from a qualitative and non-qualitative perspective. The author argues that measuring quantitative performance is actually straightforward, whereas qualitative performance is more difficult to assess and quantify. Table 5.4 summarizes the classification proposed by Chan (2003).

Table 5.3 Types of supply chain performance

Metric or attribute	Type of performance
Inventory levels	Operational (non-financial)
Product quality	
Delivery times	
Customer satisfaction	
Costs	
Environmental costs	Economic (financial)
Cash flow	
Waste	Environmental

Table 5.4 Classification of performance, according to Chan (2003)

Metric (aspect)	Type of performance
Quality	
Flexibility	
Visibility	Qualitative
Innovation	
Costs	
Resource utilization	Quantitative

Costs are a non-financial metric that includes costs related to distribution, manufacturing, inventory, and storage, or also intangible costs, overhead costs, and long-term costs. As for resource utilization, a supply chain can use resources of various kinds, such as manufacturing resources (machines, equipment, and tools), materials and inputs, human resources, storage resources, logistic resources. On the other hand, a company's performance can be qualitatively assessed in terms of quality, for example, which considers customer satisfaction, delivery lead time, rate of complete orders, stockout probability, and accuracy. As for flexibility, it comprises labor flexibility, machine flexibility, machine handling flexibility, process flexibility, and production flexibility.

In their work, Zailani et al. (2012) address performance aspects in the implementation of sustainable supply chain practices. The authors summarize four main categories of performance: economic, environmental, social, and operational. They discuss economic performance through metrics such as sales, market, waste and waste-derived costs, and resource utilization efficiency. On the other hand, environmental performance is discussed through compliance to regulations, use of energy, and use of toxic materials. Then, social performance comprises corporate image, supply chain partner relationships, and product image. Finally, operational performance includes manufacturing costs, inventory turnover rate, and the ability to quickly respond to demand variations and to changes in competitor product offerings. From a different perspective, Carvalho et al. (2012) propose to differentiate operational performance from economic performance as follows: operational performance includes quality, delivery, flexibility, cycle efficiency, and inventory levels, whereas economic performance includes cash flow, value added, costs, return on investment and efficacy.

To Ganga and Carpinetti (2011), supply chain performance attributes include:

- Reliability: whether the right product is delivered to the right place, in the right quantity, at the correct time, with the correct documentation, and to the right customer.
- Responsiveness: how fast a supply chain provides products to customers?
- Flexibility: the agility of a supply chain to respond to market changes in demand in order to gain or keep its competitive advantage.
- Costs: all the costs related to the operation of a supply chain.
- Asset management efficiency: the efficiency of an organization in managing its resources to meet demand.

Non-financial supply chain performance indicators can be classified into time, flexibility, quality, and innovation (Shepherd and Günter 2010), although experts also suggest to take into account suppliers, internal operations, distribution, and customer service (Gopal and Jitesh 2012; RajaGopal 2009). Some experts, in agreement with the Council of Supply Chain Management Professionals (CSCMP), claim that main areas of activity to measure supply chain performance are the departments of procurement, production, logistics, new product development, order management, and supply chain diagnostic. On the other hand, Gunasekaran and Kobu (2007) suggest considering the following basic criteria for supply chain performance measurement:

- A balanced scorecard perspective built on five elements: financial, customers, internal processes, innovation and improvement, and employees.
- Components of performance measures: resource utilization, outputs, and flexibility.
- Location of measures: in four phases: plan, source, make, and deliver, as defined by the SCOR model.
- Decision levels in a supply chain management system: strategic, tactical, and operational
- Nature of measures: financial and non-financial
- Supply chain performance measurement bases: qualitative and quantitative
- Traditional vs. modern measures: value-based and function-based.

These elements provide a comprehensive method to measure supply chain performance; moreover, the listing suggests that value added is not merely a specific business function, but rather a supply chain trend.

In conclusion, supply chain performance has been measured from so many perspectives and through a variety of attributes. As their contributions, many authors have conducted literature reviews to identify trends in supply chain performance measurement, especially since 2001, when it once more became important to assess corporate competitiveness, goals, and strategies. Among the main

Table 5.5 Supply chain performance categories

Categories	Authors
Qualitative	a; b; c; d; f; g; h; i
Quantitative	b; c; d; e; f; i; j; k; l
Economic	e; m; n; o
Operational	h; m; o; p
Financial	a; n; q; r; s; t
Non-financial	r; s; t

Source Adapted from Ilkka (2015), Leończuk (2016), Maestrini et al. (2017)

a: Chan et al. (2003), b: Chan and Qi (2003), c: Li et al. (2005), d: Chimhamhiwa et al. (2009), e: Witkowski (2010), f: Kowalska-Napora (2011), g: Shepherd and Günter (2011), h: Neeraj and Neha (2015), i: Kazi and Ahsan (2014), j: Ganga and Carpinetti (2011), k: Li et al. (2007), l: Ren (2008), m: Carvalho et al. (2012), n: Cho et al. (2012), o: Zailani et al. (2012), p: Gunasekaran et al. (2004), q: Golrizgashti (2014), r: Thakkar et al. (2009), s: Stefan (2004), t: Rodriguez-Rodriguez et al. (2010)

performance categories, we can find six. Research works tend to analyze performance from qualitative, quantitative, financial, non-financial, operational, and economic perspectives (Leończuk 2016; Maestrini et al. 2017; Ilkka 2015). Table 5.5 summarizes of the six supply chain performance trends across the reviewed works.

These works have analyzed attributes such as costs, quality, flexibility, resource utilization, reliability, complete delivery rate, and time through multiple techniques and methods. Therefore, the following section aims at discussing such performance evaluation techniques and methods and their suitability when evaluating the different types of performance (e.g., qualitative and quantitative). In fact, the quality and objectivity of performance evaluation results largely depend on the suitability of the method or technique that is being used. Therefore, if companies do not rely on a proper performance evaluation methodology, it is impossible to establish improvement criteria, let alone to gain the desired competitiveness.

5.3 Supply Chain Performance Measurement Models

Some of the most common ways to analyze the use of techniques for supply chain performance evaluation include conceptual models (Gunasekaran et al. 2001), surveys (Gunasekaran et al. 2004), case studies (Cuthbertson and Piotrowicz 2011), qualitative models (Chithambaranathan et al. 2015), literature reviews, and descriptive analysis. Recently, there has been an increasing interest in quantitative models for supply chain evaluation, which have proposed techniques such as multicriteria techniques (Chithambaranathan et al. 2015), statistical techniques (Ahi and Searcy 2015), mathematical programming (Gong 2008), artificial intelligence (Ganga and Carpinetti 2011), simulation (Bhaskar and Lallement 2008), and mathematical modeling (Chan et al. 2014). Authors have also conducted literature reviews to classify current performance evaluation methodologies and techniques, identify trends in supply chain performance evaluation, and propose new frameworks (Akyuz and Erkan 2010; Gopal and Jitesh 2012; Maestrini et al. 2017; Balfaqih et al. 2016; Najmi et al. 2013).

One of the most common techniques for supply chain performance evaluation is Analytic Hierarchy Process (AHP). AHP is a multicriteria technique for dealing with complex decision making. The technique captures both subjective and objective aspects of a decision by reducing it into a set of pairwise comparisons and synthesizing the results. When using AHP, performance is analyzed throughout various hierarchical levels, considering metrics at the strategic, tactical, and operational levels. AHP has been used in frameworks to comprehensively evaluate the performance of the entire supply chain (Askariazad and Wanous 2009; Thakkar et al. 2009; Cho et al. 2012; Elgazzar et al. 2012), but it has also been used to formulate a fuzzy algorithm (Yang et al. 2011), or to develop an Analytic Network Process (ANP) to quantify performance based on dependencies among multiple hierarchies from both intra- and inter-organizational perspectives (Drzymalski et al. 2010; Bhattacharya et al. 2014). In this sense, ANP is a more generalized way of using multicriteria decision analysis. Whereas AHP structures a decision as an alternative, ANP structures a decision as a network of probabilities (Bhattacharya et al. 2014).

The SCOR model is another way of evaluating performance metrics. It set some of the grounds for new and modern performance measurement and evaluation techniques and takes its name after Supply Chain Operations Reference. The model was first introduced in 1996 by the Supply Chain Council (2010). It is considered by many as the most rigorous method for supply chain performance evaluation. The SCOR model includes five basic supply chain processes—plan, source, make, deliver, and return—and a wide range of metrics organized and classified depending on five characteristics: responsibility, reliability, flexibility, costs, and assets. It is a reference framework that relates the best supply chain practices to their corresponding performance metrics. Applications of the SCOR model are widely reported in the literature. For instance, Thakkar et al. (2009) used it to report a series of performance measures for small- and medium-sized enterprises (SMEs), whereas Drzymalski et al. (2010) proposed a method for aggregating performance measures of a multi-echelon supply chain using SCOR metrics. The SCOR model has also been used to develop a simulation-based dynamic supply chain analysis tool (Persson 2011) or to propose a way of ensuring supply chain quality performance (Li et al. 2011). Similarly, another study analyzes procurement activities and their metrics with the SCOR model through gradual regressing (Stepwise) in Taiwan's TFT-LCD television industry (Hwang et al. 2008).

Simulation-based research suggests supply chain design alternatives based on performance metrics such as quality, delivery times, and costs (Persson and Olhager 2002). The main goal of simulation techniques in supply chain performance evaluation is to model the interrelationships among supply chain elements. For instance, researchers Galasso et al. (2016) performed a simulation of discrete events to develop a quantitative model to select a successful interoperability solution. On the other hand, Data Envelopment Analysis (DEA) has been proposed as a technique for measuring supply chain efficiency because it requires that all the data, both incomings and outgoings, be known. Similarly, DEA has been employed to evaluate supply chain benchmarking (Wong and Wong 2008), examine decision-making efficiency in public hospital laboratories (Abu Bakar et al. 2009), and evaluate supply chain performance under uncertainty conditions (Xu et al. 2009). Additionally, Gunasekaran et al. (2004) suggested applying DEA along with some parametric methods in order to measure supply chain performance at specific time periods, whereas Parkan and Wang (2007) combined DEA and operational competitive rating analysis (OCRA) to obtain a supply chain's overall performance profile.

Finally, supply chain performance evaluation has also relied on methodologies such as factor analysis, linear regression, and structural equations to describe the interrelationships among supply chain variables. Each one of these methodologies provides estimations to comprehensibly explain the current dynamic behavior of supply chains. Therefore, they are valuable tools for delving into new supply chain performance evaluation techniques through the study of supply chain behavior.

5.4 Performance Benefits

Supply chain performance is always associated with benefits, which are also used to implement new improvement strategies. Supply chain performance evaluation provides many advantages. For instance, it allows companies to evaluate and control progress, highlight achievements, better understand key processes, detect potential problems, and identify improvement actions and opportunities (Ahi and Searcy 2015). Likewise, evaluating supply chain effectiveness and efficiency implies associating performance indicators with performance objectives, such as costs, agility, responsibility, flexibility, sustainability, reliability, commitment, cooperation, integration, and resource utilization. That said, supply chain performance evaluation can be challenging, as it involves various supply chain actors (e.g., suppliers, customers, retailers, distributors) and must overcome multiple obstacles, such as a lack of connection and metrics, a lack of communication among actors, and the decentralization of data (Jalali Naini et al. 2011); all these obstacles can prevent companies from reaching the desired performance goals. Some benefits will be explained in chapter seven.

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Chapter 6
Supply Chain Performance Factors in the Manufacturing Industry

6.1 Overview

As in any other type of industries, performance in manufacturing companies is evaluated to improve the supply chain, either from the inside out or vice versa through the participation of all supply chain actors. The purpose of performance evaluation is to clearly and systematically improve the production system while simultaneously building good customer relationships. These goals can be attained through agility in deliveries and flexibility in the use of resources in order to address customer needs, yet both agility and flexibility are not easy to reach. Certainly, modern supply chains operate in challenging environments where a great number of factors affect performance results. Six of these factors are economic or business forces that can be listed as follows (Coyle et al. 2013):

- Customer demand
- Globalization
- Information technologies
- Competition
- Government regulations
- Environment

Globalization has promoted a geopolitical and economic environment characterized by an internal competition where companies seek to minimize their global networks. This is manifested through both political and economic threats (Coyle et al. 2013). Consequently, most companies care about their operational strategies in order to survive in such a competitive market environment, and in this sense, they tend to wonder the following as regards their business:

– Where should we offer our products?
– Where should we manufacture our products?
– Where should we commercialize our products?
– Where should we storage our products?
– How should we transport our products?

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Another challenge to supply chain management is product life cycle. Product life cycles are getting shorter over time as a result of rapid product obsolescence, rapid product development and innovation, increasing government support in manufacturing and commercial activities, terrorist acts, natural disasters, borderless organizational structures, and global competition. Similarly, current customer demands have set the greatest challenges to supply chains, since modern customers are more educated and informed and thus have greater decision-making power. In other words, today, there is no customer loyalty per se due to the great amount of products that are always available and the ability of end users to compare similar goods anytime anywhere before making a purchase. In this sense, accelerated technological progresses have contributed to this matter.

All the aforementioned factors have significant effects on the supply chain (Roldán 2006) as well as on the way companies operate in order to remain competitive. Some of these effects include:

- Customers demand a better service and more purchasing alternatives.
- Customers demand low prices.
- Products can be shipped to and from anywhere in the world.
- Information technologies facilitate decision making in order to improve timing and increase reliability.
- Environmental awareness and regulations put pressure on companies to reduce waste and reuse materials and consequently demand changes in supply chain design and operation.
- Competition has exponentially increased thanks to technological progresses, information availability, business design creativity, and globalization.

All these changes place companies at a crossroads. They must be able to orient their business strategies toward the globalization of processes and consequently develop a new way of being and remaining competitive. In such difficult situations, supply chain performance evaluation has gained importance, not only because products are expected to be timely delivered, but also because they must have the highest possible value added. In the pursuit of competitiveness, companies measure their outcomes at every stage of the supply chain to compare their performance with that of their competitors.

Export-manufacturing companies usually adopt supply chain evaluation approaches from the inside out. They implement lean manufacturing practices to improve their processes and increase product quality; at the same time, they minimize both waste and production costs. As previously mentioned, export-oriented manufacturing companies belong to complex supply networks, as they are intimately linked with parent companies from an operational perspective. Therefore, they are required to constantly evaluate their performance as competitive and high-quality manufacturers. Many of these companies make constant performance improvements thanks to the implementation of industrial engineering concepts and tools that demand the involvement of all the employees. Undoubtedly, active participation allows organizations to achieve the best long-term benefits.

In the following section, we discuss some works that have studied supply chain performance in the manufacturing industry. It is important to mention that both lean manufacturing tools and work philosophies (e.g., just in time) are widely used in the industrial sector, especially because manufacturing companies belong to large and complex supply networks and are asked to comply with specific levels of production, quality, and customer satisfaction.

6.2 Factors Associated with Performance in the Manufacturing Industry

Modern companies seek to increase production process efficiency through the supply chain, which allows them to minimize costs and increase product quality and agility. Supply chain performance can be evaluated through a series of attributes and controllable variables that minimize risks in production, suppliers, and demand (Bhatnagar and Sohal 2005). Similarly, supply chain performance can be improved by modifying its operational structure, processes, or even business processes in order to meet customer needs and increase profits.

Supply chain has been increasingly studied over time through attributes and/or variables that are analyzed using a broad range of methodologies, from descriptive analyses to fuzzy logic. Some works have focused on the implementation of information technologies to streamline information processing and improve communication and coordination among supply chain actors, whereas others have sought to develop marketing strategies to diminish the bullwhip effect. Globalization has made companies search for and implement novel management tools and strategies to improve their performance and customer satisfaction through greater production flexibility, availability, and information quality. The performance of corporations such as Toyota, Dell, and Walmart relies on the supply chain management practices and technologies they implement (Kim 2006; Kovács and Paganelli 2003).

In the Mexican industry, most of the supply chain-related studies propose new supply chain management techniques. Likewise, international logistics has been considered in order to evaluate supply chain efficiency aspects (e.g., supplier coordination and cooperation, information sharing, import processes, contingency plans) and determine how these aspects influence on performance characteristics, such as synergy among supply chain members, cash flow, complete orders, costs, and lifecycle times (Avelar-Sosa et al. 2015).

Another study evaluated the relationship between absorption, innovation, and responsiveness capabilities with supply chain performance. The study takes into account suppliers, agility, and work resources/method development capabilities, among others (Monge and Guaderrama 2016). On the other hand, Total Productive

Maintenance (TPM) has been used to identify critical supply chain stages that need improvement in order to prevent machine idle times, downtimes, slowdowns, defective products (Alcaráz et al. 2015). Likewise, structural equation models are popular tools for visualizing corporate benefits as a result of total quality management (TQM) practices (Gil et al. 2015), or to understand the effects of green supplier attributes on the environment and their impact on high-quality green products (Fong et al. 2016).

In the manufacturing industry, the procurement process has been examined to determine its impact on supply chain efficiency in terms of inventory levels, deliveries, and customer satisfaction (Alcaraz et al. 2013). Likewise, kaizen has been associated with performance benefits at all its stages, from planning to implementation control (Vento and Alcaraz 2014), and SMED implementation stages have been related to certain industrial benefits, such as shorter setup times, which have an impact not only on production capabilities and order fulfillment, but also on production costs, waste, productivity, and product quality (Díaz-Reza et al. 2016). From a different perspective, works such as that proposed by Avelar-Sosa et al. (2014b) consider external factors such as the environment, services and services-related costs, and infrastructure to value their influence on quality and customer service in the supply chain.

All the reported works highlight operational factors that present certain risks in suppliers and demand. There is a wide range of alternatives to assess the impact of risk factors on supply chain performance. In this sense, we can also notice that there is great number of factors associated with supply chain performance in the manufacturing industry, and most of them are approached from an economic or organizational perspective, or they are studied in such a way as to encourage the modification and adaptation of industrial operations and processes to provide immediate solutions to companies.

Considering the works discussed earlier, there are three aspects to take into account when evaluating a supply chain: (1) the presence and perception of risk, both inside and outside of the supply chain, (2) manufacturing practices, and (3) and environmental factors (i.e., geographic location), which comprise infrastructure, services, government, and market proximity. As Bhatnagar and Sohal (2005) suggest, supply chain performance results depend on both particularities and the environment, which is why competitiveness depends on both operational aspects and the specific characteristics of human resources and the environment where companies operate. In other words, supply chain does not only depend on the organizational structure or on the way this structure is managed. It also depends on the regional aspects that interact with a company’s resources in order to achieve the desired business goals.

The modern manufacturing industry is an important element for productivity and economic growth and has crucial implications. The generation of jobs in the manufacturing sector promotes economic development, contributes to a country’s gross domestic product (GDP), and increases life quality. In turn, the supply chain of the manufacturing industry improves production system control and promotes adequate collaboration among companies that are supply chain partners. Similarly, it unifies goals and objectives to create a solid competitive advantage (Zeng and Yen 2017). In countries such as Taiwan, China, Hong Kong, Australia, and the USA, studies on the supply chain are varied; they include literature reviews and evaluation models and propose alternatives such as performance evaluation metrics and the use of technology to improve benefits. In all cases, the ultimate goal is to help companies and supply chains achieve their business objectives through an evaluation of processes, activities, and impact factors, such as supplier capabilities, customer demands, designs, geographic location, timing. Clear examples of successful supply chains are Toyota, Dell, and Walmart, which have steadily improved their management practices and have wisely embraced new technologies.

Nowadays, companies should achieve greater efficiency at the lowest possible costs and without compromising customer service if they want to remain competitive. As Porter (1985) claims, every competing firm must have a competitive strategy, either implicitly or explicitly; therefore, a correct supply chain evaluation must integrate all supply chain actors at the tactical and operational levels. The elements discussed in this book as performance impact factors have been studied through multiple and varied techniques because they represent performance improvement opportunities. That said, measuring performance requires a process-content context that involves specific supply chain and firm characteristics. In other words, performance measurement takes into account a company's organizational structure and characteristics along with the environment when this company operates (Richard and Wojciech 2011). That is why this book emphasizes on and takes into account externalities to address supply chain performance measurement and evaluation. The following subsections thoroughly review the three key factors to be considered in supply chain evaluation, namely supply chain risk, manufacturing practices, and environmental factors. These elements are the foundation of this book in order to evaluate supply chain performance in the manufacturing industry of Ciudad Juárez.

6.3 Supply Chain Risk

6.3.1 Definition of Risk and Risk Management

Supply chain risk is associated with the logistics activities that manage the flow of materials and information. It emerges as a result of current economic crises, natural disasters, globalization, and dynamic and changing markets and supply chains (Braunscheidel and Suresh 2009; Tang and Tomlin 2008). Risk is present in any supply chain. In every offered product or service, there is a different level of associated risk. As a definition, risk is the probability of an incident associated with inbound supply from individual supplier failures or the supply market occurring, in which it outcomes result in the inability of the purchasing company to meet customer demands or cause threats to customer life and safety (Cheng et al. 2012).

To others, supply chain risk is a negative deviation from the expected value of a certain performance (Wagner and Bode 2008), the potential variation of outcomes that influence the decrease of value added (Bogataj and Bogataj 2007), or the likelihood and impact of unexpected macro- and micro-level disruptions or events that adversely influence any part of a supply chain, leading to operational, tactical, or strategic level failures or irregularities (Cheng et al. 2012; Ho et al. 2015).

Supply chain risk sources involve suppliers, customers, and demand alike. Demand risks are caused by unpredictable or misunderstood customer or end-customer demand. Some experts claim that decision makers must consider uncertainties in supply chain planning phases, including demand. Explicitly, it is important to consider potential risks derived from suppliers and manufacturers (Snyder et al. 2006). Supply chain management is seen as an interorganizational collaborative endeavor that relies on qualitative and quantitative risk management methodologies to identify, evaluate, mitigate, and monitor macro- and micro-level events or unexpected disruptions that might adversely affect any part of a supply chain (Cheng et al. 2012; Ho et al. 2015).

Risk is manifested through different types of individual risks that affect supply chain performance (Daniel et al. 2012; Ho et al. 2015). In this sense, supply chain risk sources are usually classified into three groups: environmental risk, organizational or internal risk, and network-related risk. Environmental risks derive from external forces, such as rain, earthquakes, wars, government policies, social trends, and market trends. They comprise any uncertainty caused by the interaction between the supply chain and its physical, social, political, legal, and economic environments (Bogataj and Bogataj 2007). On the other hand, organizational risk comprises risks related to inventories, processes, quality, or management practices; that is, those derived from work- and process-related aspects (Chopra et al. 2007; Jüttner et al. 2003). Also, operational risks arise as a result of new operational events or flow interruptions in the supply chain (Colicchia et al. 2010; Lockamy and McCormack 2010). Also, sometimes it is assumed that operational risks emerge from subcontracting activities, which are also potential sources of network-related risks (Kaya and Özer 2009).

Finally, network-related risks occur from the interactions among supply chain partners and include supplier risks and demand risks. Similarly, network-related hazards involve a whole organization and all the aspects related to its management (Jüttner 2005), including its communication, cooperation, and integration with the other supply chain members. Risk is generally viewed as a source of uncertainty and a series of disruptions occurring in the processes among suppliers and demand (Tang and Musa 2011).

Processes risk results from the perception of uncertainty in the processes due to machine and equipment failures. Demand risk is perhaps the most serious problem, as it emerges from an inaccurate demand forecast (Bhatnagar and Sohal 2005). In general, supply chain risk compromises performance and has adverse effects on inventory costs, delivery lead times, flexibility, responsibility, and reliability. In this book, risk will be viewed as the set of unperformed activities and disruptions that emerge in each supply chain stage and cause adverse effects on supply chain performance. Risks must never be neglected when evaluating supply chain performance results, as their consideration enables to establish appropriate risk management strategies and criteria. Companies approach supply chain management from different perspectives depending on the type of service or product they offer, yet in all cases, supply chain management strategies aim at increasing performance and therefore flexibility in order to successfully meet customer demands at the lowest possible production costs. In this sense, risk management should be an inherent part of supply chain management. Risk management can be separated into four stages: risk identification, risk assessment, risk treatment, and risk monitoring (Hallikas et al. 2004). Risks cause important economic and productivity losses, yet they are an inherent phenomenon in any system. They reflect on late deliveries, production capabilities, and costs, to name but a few. Overall, they occur as a result of market dynamism, technological progress, an increase of competitors, government policies, or natural disasters, which prevent either raw materials or end products to be delivered on time.

6.3.2 Risk Assessment Methodologies

Risk assessment covers a whole spectrum of methodologies aimed at identifying risk sources and establishing risk mitigation strategies. Common risk assessment methodologies include simulations, descriptive and statistical analyses, Bayesian modeling, linear regression, reverse logic, and conceptual models, to name but a few. Bayesian models have been used for developing a knowledge integration framework for complex network management (Xiangyang and Charu 2007) and for evaluating supply chain reliability (Klimov and Merkuryev 2008). On the other hand, Monte Carlo simulations have proven to be useful in supplier risk assessment (David and Desheng 2011), whereas system dynamics has been utilized to evaluate the bullwhip effect (Disney et al. 2008), assess supply chain terrorism (Bueno-Solano and Cedillo-Campos 2014), and identify the relationship between supply chain risks and performance in terms of costs, quality, and delivery times (Guertler and Spinler 2015).

Fuzzy logic approaches have aimed at evaluating logistics and risk mitigation strategies in the area of product design (Tang et al. 2009), while a linear regression based study has been proposed to estimate supply chain vulnerability (Bogataj and Bogataj 2007). On the other hand, experts have applied stochastic criteria for risk management in global supply chain networks (Goh et al. 2007). Analytic hierarchy process (AHP) has been used for supporting offshoring decision making (Schoenherr et al. 2008), selecting suppliers (Kull and Talluri 2008; Schoenherr et al. 2008), and evaluating supplier risk (Wu et al. 2006). Meanwhile, conceptual frameworks are developed in order to manage volatility-induced risk in the supply chain (Martin and Matthias 2017) and prevent, monitor, and control supply chain risk (Sarkar 2017). In turn, structural equation models have been developed to assess supplier risk perception from buyers with respect to supplier reliability and joint benefits (Cheng et al. 2012) and to determine the impact of supply chain risk on supply chain flexibility and customer service (Avelar-Sosa et al. 2014a).

Statistical models and simulations have been used to evaluate risk mitigation elements and improve efficiency in manufacturing industries (Talluri et al. 2013), and a P-chart model has been used to evaluate supplier risk management, and consequently, eliminate bottlenecks and minimize costs (Sun et al. 2012). Other works propose theoretical frameworks on supply chain flexibility (Tang and Tomlin 2008), risk in small and medium-sized enterprises (SMEs) (Mohd Nishat et al. 2007), and uncertainty (Jyri et al. 2014). From a different perspective, Bueno-Solano and Cedillo-Campos (2014) propose and analyze a set of terrorism factors that affect supply chain performance, whereas Chad and Bobbitt (2008) and Hoffmann et al. (2013) identify a series of safety impact factors perceived by managers. All these works propose ways of tacking supply chain risk without forgetting that risk itself in inherent in any system. It occurs simply because a supply chain is a group of interrelated companies sharing meaningful flows of materials, information, and money. Any failure or disruption at any supply chain stage affects previous and subsequent stages and directly and indirectly affects performance outcomes.

Stochastic linear programming has been used for risk management assessment, considering inventory planning, or for demand disruption assessment (Qiang and Nagurney 2012; Radke and Tseng 2012). Likewise, genetic algorithms have been applied to assess multiple sourcing activities under supplier failure risk and quantity discount (Meena and Sarmah 2013), and an approach based on graph theory has managed to calculate supply chain vulnerability through supplier–customer interdependence (Wagner and Neshat 2010).

Finally, Bayesian networks have been implemented to evaluate the impact of supplier and network-related risks on company performance (Lockamy and McCormack 2010). Table 6.1 summarizes these works. As can be observed, studies on supply chain risk mainly focus on risk mitigation, risk management, supplier evaluation, and supply chain flexibility and security.

The literature review shows rising trends in supply chain risk management. As (Bhatnagar and Sohal 2005) point out, business competitiveness is attached to operational risk factors, supply risks factors, and demand risk factors. Many research works have demonstrated the importance of risk assessment in supply chain management by considering risk as an inherent element in all supply chain stages and all supply chains. That said, it is important to identify the different source of risk to find the best ways to assess them and tackle them. In this sense, the following subsection addresses the various sources of demand risks, supplier risks, and production process risk as well as their impact on supply chain performance.

Table 6.1 Risk attributes and risk assessment methodologies

Author	Element	Methodology
Bhatnagar and Sohal (2005)	Location, performance	Linear regression
Wu et al. (2006)	Suppliers	AHP
Faisal-Cury and Menezes (2007)	SMEs risk	Descriptive analysis
Li and Chandra (2007)	Information	Bayesian analysis
Goh et al. (2007)	Global supply chains	Stochastic processes
Wu and Olson (2008)	Suppliers	Monte Carlo simulation
Towill and Disney (2008)	Bullwhip effect	Dynamic of systems
Kara and Kayis (2008)	Bullwhip effect	Dynamic of systems
Schoenherr et al. (2008)	Suppliers	AHP
Klimov and Merkuryev (2008)	Survival	Simulation
Autry and Bobbitt (2008)	Security	Descriptive analysis
Williams et al. (2008)	Security	Descriptive analysis
Tang and Tomlin (2008)	Flexibility	Descriptive analysis
Kull and Talluri (2008)	Suppliers	AHP
Tang et al. (2009)	Risk management	Fuzzy logic
Wagner and Neshat (2010) Lockamy and McCormack (2010)	Risk management Supplier risk	Graph theory Bayesian networks
Cheng et al. (2012) Sun et al. (2012) Qiang and Nagurney (2012) Radke and Tseng (2012) Talluri et al. (2013) Meena and Sarmah (2013)	Risk management Risk management Supply risk Risk management Risk management Risk mitigation Supply risk	Literature review Structural equation modeling P-chart model simulation Stochastic linear programming Stochastic linear programming Statistical methods and simulation Genetic algorithm
Hajmohammad et al. (2014) Avelar-Sosa et al. (2014) Manuj et al. (2014) Ho et al. (2015) Heckmann et al. (2015) Rajesh and Ravi (2015)	Supplier sustainability risk Risk management Risk management Risk management Risk management Risk mitigation	Descriptive analysis Structural equation modeling Simulation Literature review Literature review DEMATEL method
Martin and Matthias (2017)	Risk mitigation	Statistical methods and simulation

Source Prepared by the authors

6.3.3 Types of Supply Chain Risk

There is no unified method to classify supply chain risk. Each research work contributes in its own way to a better understanding of risk sources in supply chain environments, especially because supply chains are varied. Some authors have proposed to classify supply chain risk into internal risk and external risk (Ch and Himpel 2013; Flynn 2009; Narasimhan and Talluri 2009; Wu and Olson 2009). The former refers to those disruptions that arise inside of companies (risks in processes) and in the supply chain network (supplier and demand risks), whereas the latter comprises external risk factors (e.g., natural disasters, wars, terrorism, and political instability. From a slightly different perspective, supply chain risk has been classified into micro-risk and macro-risk, depending on its impact (Ravindran et al. 2010; Tang 2006). After conducting a literature review on supply chain risk management, Ho et al. (2015) categorized natural disasters, terrorism, political environment, accidents, and wars as macro-risk factors, whereas micro-risk factors comprise demand, manufacturing processes, and suppliers. This book assesses the micro-risk factors discussed by Ho et al. (2015) in their literature review. To summarize this review, we present Table 6.2, which details the types of supply chain risks along with their corresponding factors and elements.

Table 6.2 Supply chain risk types, factors, and elements

Risk type	Risk factor	Element	Authors
Internal	Supply, demand, production or manufacturing, transportation and distribution risk, capacity, operational, logistics, network, infrastructural risk, information risk, financial risk	Procurement delay, material flow, physical plant, inventory, information flow, financial flow, quality, information delays, costs, technology, transparency, behavioral and political, bullwhip effect, flexibility, product obsolescence, demand uncertainty	Samvedi et al. (2013), Hahn and Kuhn (2012), Tang and Musa (2011), Tummala and Schoenherr (2011), Kumar et al. (2010), Tuncel and Alpan (2010), Tang and Tomlin (2008), Wagner and Bode (2008), Manuj and Mentzer (2008), Bogataj and Bogataj (2007), Wu et al. (2006); Tang (2006), Cucchiella and Gastaldi (2006), Chopra and Sodhi (2004), Cavinato (2004)
External	Natural disasters, terrorism, accidents, exchange rate fluctuations, political system, market, competitors, economic crises	Hurricanes, floods, earthquakes, inflation, contagious diseases, employee strikes, consumer prices, index changes, exchange rate fluctuations	Hahn and Kuhn (2012), Kumar et al. (2010), Olson and Wu (2010), Trkman and McCormack (2009), Wagner and Bode (2008), Kull and Talluri (2008), Blackhurst et al. (2008), Wu et al. (2006), Tang (2006), Chopra and Sodhi (2004).

Adapted from Ho et al. (2015)

6.3.3.1 Demand Risks

Synchronizing supply with actual demand in a supply chain is a challenging endeavor. It is a complex task itself, and also, there is always a certain degree of demand uncertainty in the market, which is known as implicit uncertainty. Risk propagates both downward and upward in the supply chain and therefore affects demand. In this sense, demand risks is a set of adverse effects at the downstream partners of a firm (Zsidisin 2003; Wagner and Bode 2008). Likewise, demands risk includes risks associated with turbulent environments and unstable and dynamic customer needs. Unstable demand is generally the biggest challenge for modern companies, as it leads to high inventory levels, low levels of customer service, and unreliable deliveries (Chen and Paulraj 2004). Demand risks is a micro-risk factor (Ho et al. 2015) and is mainly caused by elements such as information distortion, the bullwhip effect, inaccurate demand forecasts, short lifecycles, demand variability, high market competition, and low in-house production.

Risks at the demand stage imposes great challenges, since modern businesses rely on demand-driven production models; that is, just-in-time models that produce only when a customer places an order (customer demand) to satisfy that demand. Demand risks must be visualized through a systematic evaluation of potential risks in the company in order to establish anticipated solutions that prevent greater risks and monetary losses. A categorization of demand risk elements can be consulted in Table 6.3. The first column lists the risk elements reviewed in the literature, the second column includes the works that address these elements, and the third column

Table 6.3 Demand risks elements

Element	Author	Frequency
Demand forecast	Ho et al. (2015), Hahn and Kuhn (2012), Samvedi et al. (2013), Kim (2013)	4
Bullwhip effect	Udenio et al. (2017), Raghunathan et al. (2017), Ho et al. (2015)	3
Demand uncertainty	Ho et al. (2015), Hahn and Kuhn (2012), Samvedi et al. (2013), Bhatnagar and Sohal (2005), Su and Yang (2010)	5
Demand inaccuracy	Ho et al. (2015), Tang and Musa (2011), Kang and Kim (2012)	3
Demand visibility	Ho et al. (2015), Avelar-Sosa et al. (2014), Bhatnagar and Sohal (2005), Su and Yang (2010)	4
Information distortion	Ho et al. (2015), Bhatnagar and Sohal (2005), Su and Yang (2010)	3
Poor communication	Ho et al. (2015), Bhatnagar and Sohal (2005), Su and Yang (2010)	3
Outsourcing	Ho et al. (2015)	1
Order fulfillment errors	Ho et al. (2015)	1

Source Prepared by the authors

lists the frequency of appearance of these elements in the literature. Some aspects of demand risk considered are demand forecast, demand visibility, demand inaccuracy, information distortion in supply chain, and poor communication across members, bullwhip effect, error on fulfillment of orders, etc.

In the following paragraphs, we provide an overview of these elements to highlight their importance in supply risks management and hence in supply chain performance evaluation.

Demand Forecast

Forecasting is a key element in any organization. It sets the grounds for long-term plans, budget planning, and costs management. Marketing departments depend on sales forecasts to quantify their plans for new and existing products, evaluate their sales strategies, and assess promotional impacts that optimize fundamental decision making. Similarly, production staff and operators rely on production forecasts to make regular decisions about the production processes, inventories, and programs and to plan an adequate facility layout (Jacobs and Chase 2005). Finally, forecasting allows capacity planning and therefore ensures that the resources are well managed so that customer demand is met in the right amount, at the right time, and with the right quality (Hahn and Kuhn 2012; Kim 2013; Martínez et al. 2015).

Bullwhip Effect

The bullwhip effect is the phenomenon of demand amplification and distortion in a supply chain. Demand variability increases as it is transmitted along the supply chain links and therefore translates into an increase of uncertainty for decision makers, thereby affecting supply chain activities (Romero et al. 2017). The bullwhip effect was named for the way the amplitude of a whip increases down its length. A small variance in real customer demand can disrupt the regular upstream flow of the supply chain and therefore compromise the flow of information in manufacturers, which are unable to produce what is requested. Similarly, the bullwhip effect refers to a phenomenon where supplier orders have bigger variance than sales to the buyer, and the alteration propagates upstream in an enlarged form (Disney and Towill 2003; Udenio et al. 2017).

Demand Uncertainty and Inaccuracy

Demand inaccuracy can be understood as the degree to which demand is erroneously estimated due to controllable factors associated with supply chain operations. On the other hand, demand uncertainty refers to those disruptions caused by wrong long-term projections of customer demand. The causes of demand uncertainty are exogenous and include environmental and operational conditions, changes in customer interests, technology development, and the number of competitors a business faces, among others (Bolaños and Correa 2014; Kang and Kim 2012). Both demand uncertainty and inaccuracy can have adverse effects on supply chain performance (Bhatnagar and Sohal 2005; Samvedi et al. 2013; Su and Yang 2010).

Demand Visibility

Supply chain visibility is the ability to share on-time and accurate data on customer demand, amount and location of inventory, transportation costs, and other logistical aspects (Hendricks and Singhal 2003). Therefore, demand visibility is a company's ability to share real time, on-time, and accurate data on product requirements through the use of information technologies and systems. Some authors suggest that in order to mitigate demand risk, it is important to increase supply chain visibility, and even its ability to look ahead. This would increase supply chain planning and efficiency and therefore effectiveness (Yu and Goh 2014).

Poor Communication

Poor communication is a major risk, as it is impossible for supply chain members to interact among them without sharing information and viewing themselves as part of a team, a network. In order to control and manage logistics, production, and financial operations along the whole supply chain, there must be an adequate collaboration, coordination, and cooperation among all supply chain partners. Such a communication approach brings benefits for all.

Outsourcing

Globalization and modern production and business models have made companies rely on outsourcing (i.e., hiring a party outside of a company to produce services and goods that were traditionally performed inside of the company). The risk of this practice mainly lies in the fact that it is impossible to control the whole transformation process inside the company's facilities. Moreover, it is difficult to maintain relationships and a solid coordination with multiple companies.

Order Fulfillment Errors

According to Sucky (2009), order fulfillment errors cause customers to receive the wrong items, and shipping and returns can be difficult and unreliable. In this sense, without an effective order fulfillment organization, it is difficult to successfully satisfy customer demand.

In conclusion, the demand risks elements or attributes discussed in this section can explain how demand risks occurs in the manufacturing industry as a result of the demand-related activities that they perform or fail to perform and their relationships with customers. Considering this review and Table 2.5 presented earlier, we can conclude that demand in the export-oriented manufacturing industry has the following four attributes (Bhatnagar and Sohal 2005; Hendricks and Singhal 2003; Su and Yang 2010):

Product demand

- is often communicated by the customer in advance.
- is transmitted in real time by customers via information systems.
- is visible for both companies and suppliers.
- is frequently stable and does not affect production scheduling.

These attributes can assess the degree of demand risks perceived by manufacturing companies as a result of both their relationships with customers and the demand management practices adopted in the supply chain.

6.3.3.2 Supply Risks

Nowadays, trade environments are complex, and supply networks fluctuate as a result of an increasing number of suppliers. Such phenomena are important supply risk sources. In the past, supply risks was rare and easier to manage, since manufacturing companies produced only within their facilities, generally relied on local suppliers, and sold mostly to local end customers. However, current consumption rates and the increasing complexity of product requirements, from design to distribution, have led to the participation of specialized companies in the production process. Moreover, deliveries now cross borders, and customers of a same product can be found anywhere around the world. Supply networks are lateral and horizontal connections and bidirectional exchanges in the upward and downward flows of a supply chain. Risk in supply networks is the consequence of an increasing pressure on manufacturers to be efficient and effective. Similarly, as a result of globalization, companies now focus on distribution strategies and outsourcing businesses, which have considerably reduced the number of suppliers in a supply network (Bogataj and Bogataj 2007).

To some authors, supply chain risks are defined as an individual perception of the total potential loss associated with the disruption of supply of a particular item purchased from a particular supplier (Ellis et al. 2010). To others,supply chain risks are potential deviations of inbound materials from the moment a purchasing order is placed, and which may result in uncompleted orders. Supply deviations have a consequence on the costs, quality, and delivery of the requested raw materials (Kumar et al. 2010). Moreover, risks are inevitable in the supply chain and emerge from deviations in the inbound materials requested by the manufacturer (Blome and Schoenherr 2011).

A study conducted by Snell (2010) revealed that 90% of companies are threatened by supply risk, whereas 60% of them do not have adequate knowledge about supply risk. On the other hand, Hendricks and Singhal (2003) found that technical failures in suppliers reduce the operating income of firms by 31.28%, whereas another study revealed that at least 40% of supply chain disruptions come from suppliers, namely Tier 2 and Tier 3 suppliers. In this sense, it is important to increase supply chain visibility and integration (LexisNexisGroup 2013). For instance, Toyota, Cisco, and P&G have made significant efforts to identify their suppliers, from Tier 1 to Tier 3 suppliers (Revilla and Sáenz 2014), which is important because we rarely see the relationships that manufacturing companies have with their suppliers.

Some authors have analyzed inbound supply chain risk from individual suppliers (Wu et al. 2006), others have claimed that supply risk assessment must include supplier capacity and responsibility (Chopra and Sodhi 2004, 2014). On the other hand, studies have emphasized on the effects of information on deliveries, demand adjustments, and other aspects requested by customers (Gaudenzi and Borghesi 2006; Su and Yang 2010; Tummala and Schoenherr 2011) or have analyzed the causes of failures in supply deliveries, including uncompleted orders, late deliveries, or poor product quality (Cucchiella and Gastaldi 2006; Chopra and Sodhi 2004; Kull and Talluri 2008; Samvedi et al. 2013). The literature also reports the effects of supplier quality on perceived supply risk (Cucchiella and Gastaldi 2006; Manuj and Mentzer 2008; Ravindran et al. 2010; Tapiero 2007) and the impact of supplier communication on supply chain integration and coordination (Sun et al. 2012; Talluri et al. 2013). Similarly, other studies have analyzed the effects of external factors, transportation systems, and supplier monitoring on supply risk (Manuj and Mentzer 2008; Meena and Sarmah 2013; Wu et al. 2006).

Table 6.4 above summarizes the main trends in supply risk analysis. As can be observed, the major sources of supply include supplier communication, supply visibility, information sharing, quality control, supplier coordination, and failed deliveries. Based on this summary and the previous discussion, we propose the following six elements or attributes used to assess supply risk in the manufacturing industry.

My suppliers:

- continuously deliver the raw materials on time.
- frequently deliver complete and accurate orders.
- continuously deliver quality materials.
- maintain a frequent communication with our company to reduce failures.
- continuously coordinate their processes with ours.
- use information systems (MRP I, MRP II, SAP).

These attributes can identify the degree of supply risks perceived by manufacturing companies as a result of both their relationship with their suppliers and their supply management practices. It is important to highlight communication as a key

Table 6.4 Supply risks elements

Element	Author	Frequency
Inbound risk	Wu et al. (2006), Manuj and Mentzer (2008), Chopra and Sodhi (2004)	3
Visibility and information sharing	Gaudenzi and Borghesi (2006), Su and Yang (2010), Bhatnagar and Sohal (2005); Tummala and Schoenherr (2011)	4
Delivery failures	Chopra and Sodhi (2004), Cucchiela and Gastaldi (2006), Kull and Talluri (2008), Tummala and Schoenherr (2011), Samvedi et al. (2013)	5
Supplier quality control	Cucchiella and Gastaldi (2006), Tapiero (2007), Blackhurst et al. (2008), Manuj and Mentzer (2008), Lockamy and McCormack (2010), Ravindran et al. (2010)	6
Supplier communication	Sun et al. (2012), Talluri et al. (2013), Su and Yang (2010), Bhatnagar and Sohal (2005), Gaudenzi and Borghesi (2006)	5
Environmental risk	Meena and Sarmah (2013), Bhatnagar and Sohal (2005), Chopra and Sodhi (2004), Manuj and Mentzer (2008)	4

Source Prepared by the authors

ingredient to make any kind of correction on time, either in product requirements or quality. Also, all supply chain members must synchronize their goals and activities with one another to extend their benefits.

6.3.3.3 Production Process Risk

Production risk factors, also known as manufacturing risk factors (Ho et al. 2015), occur in all those operational activities performed by manufacturers. Manufacturing or production risk comprises all those events or adverse situations that occur within companies and affect their internal capacity to produce the desired quality and quantity at the right time (Wu et al. 2006). Production risk affects productivity and is the result of poor reliability in the production process due to failures in procedures, human resources, machines, and support services. In order to assess production risk, we rely on the contributions of Chopra and Sodhi (2004), Tuncel and Alpan (2010), Wagner and Neshat (2010), Tummala and Schoenherr (2011), Su and Yang (2010), and Soin (2004). To mitigate production risk, these works suggest elements such as manufacturing practices, design changes, flexibility, low inventory levels, information transparency, and information technology (IT) platforms. Likewise, they address a series of activities and actions for manufacturing process improvement, such as low machine failure rates, low employee absenteeism levels, and employee motivation.

The elements that this book considers to assess production risks also address the impact of communication and collaboration among supply chain members on risk mitigation and hence on supply chain performance. Information must flow smoothly and coordinately to prevent production delays and errors, and companies must rely on the necessary support services to mitigate any potential production risks. Production departments must focus on generating and managing product quality, whereas the other departments are responsible for providing the appropriate services that guarantee the company's functions. The listing below presents the attributes used to assess the perception of production risk in the manufacturing industry. These attributes cover logistics, financial, and telecommunications services. A low level of efficiency or availability in any of these attributes causes a greater perception of risk. Therefore, production can be compromised when companies do not know for sure the demand or the transport characteristics, or when they lack the necessary facilities to manufacture their products.

My production processes:

- are highly affected by a lack of logistics services (customs, transportation, warehouses, security, legal advice).
- are highly affected by the low efficiency of financial services (banks, insurance companies, fund administration services).
- are highly affected by a lack of connectivity with target markets.
- are highly affected by the low efficiency of telecommunications services (landlines, television, radio).
- are reliable thanks to stable government policies, both fiscal and commercial policies.
- are efficient thanks to the implementation of lean manufacturing practices.

These attributes can assess the production risk perceived by manufacturing companies as a result of a lack of support services, which are necessary not only for performing internal operations, but also for communicating with external commercial activities and the environment. In this sense, the relationship between external and internal factors should never be underestimated, let alone discarded, in any risk assessment or supply chain performance evaluation. Also, considering fiscal and commercial policies as production risk attributes suggests that governmental intervention can influence a company's ability to manage its supply chain and obtain the desired benefits. This implication will be further analyzed in the third section, when we present a series of models to evaluate the effects of these attributes on supply chain performance.

In conclusion, in supply chain performance, namely supply chain risk, information technologies and financial systems (Chopra and Sodhi 2004), as well as transport systems (Wu et al. 2006) are critical factors. Any disruption in any of these systems can adversely affect supply chain performance. These three aspects give rise to the infrastructure risks suggested by (Ho et al. 2015), who propose valuable contributions to the understanding of risk in demand, supply, and production process.

6.4 Manufacturing Practices

As previously mentioned, the manufacturing industry transforms raw materials or inputs into different consumer products. Manufacturing practices are the best way to optimize production processes, and without them, it would be impossible to transform products, let alone to satisfy customer needs. Manufacturing practices are closely linked to production processes, as they allow companies to produce in an orderly and systematic way through the implementation of certain production tools and philosophies. Commonly, manufacturing practices are associated with the concept of lean manufacturing, developed in Toyota's production system and first introduced by Sakichi Toyoda. In the last 20 years, lean manufacturing practices have managed to reduce production process times by relying on the design of inter-functional equipment, rapid communication through the Internet, and process simplification. In this sense, lean manufacturing also refers to an integrated socio-technical system whose goal is to reduce waste at each stage of the production process in order to obtain more economic benefits and deliver high-quality products (Shah and Ward 2007).

Lean manufacturing has become a miraculous global methodology for process improvement. Companies around the world seek to reproduce the results obtained by Toyota in terms of profits and market penetration via the implementation and management of lean tools. As previously mentioned, lean tools aim at reducing all those activities that do not add any value to the product (i.e., waste) while simultaneously reducing inventory levels. In any lean environment, employees are the key for process improvement and business transformation.

Taiichi Ohno identified six types of waste, also known as muda, in Toyota's production system:

- Over production
- Waiting
- Unnecessary transport
- Excess inventory
- Wasted movement
- Defects

6.4.1 Toyota Production System and Competitiveness Enterprises

The Toyota Production System (TPS) refers to a set of tools and techniques for waste elimination that also optimize processes, improve product quality, and increase system productivity and efficiency. The most commonly implemented manufacturing tools are the 5s program, just in time, Six Sigma, poka-yoke, kanban, and single minute exchange of die (SMED). The continuous improvement of any production process is possible as long as the work methods are improved and monitored through these tools.

Competitiveness in such a globalized environment reveals the importance of having more efficient operational and administrative processes in order to improve customer service levels, delivery times, product/service quality, and resource utilization (Rodríguez-Méndez et al. 2015). From this perspective, manufacturers around the world strive to gain all the benefits that good lean manufacturing practices guarantee (Liker and Hoseus 2009). In a pursuit of global competitiveness, production managers become increasingly interested in knowing and managing all those factors that, at the country level, impact a business's location, supplier selection, and operational improvement (Schoenherr and Swink 2012). Lean practices have improved the flow of information along the supply chain and have made supply chain members pay close attention to costs, quality, on-time deliveries, and flexibility. Lean practices emerged from a Japanese concept whose purpose is to reduce waste (layout, materials, time, money, workforce, etc.) and improve productivity and product quality.

In order to evaluate the degree of implementation of manufacturing practices in the surveyed manufacturing companies, this book takes into account practices such as total quality management (TQM), just in time (JIT), and total productive maintenance (TPM), and manufacturing technologies such as computer-assisted design (CAD), computer-aided engineering (CAE), and computer-aided manufacturing (CAM). The following sections provide an overview of each practice in order to contextualize their use in this book and justify their effect on supply chain performance.

6.4.1.1 Quality

Quality in products or services is a profit criterion promoted by companies among suppliers in an attempt to gain a competitive advantage (Galloway et al. 2012). To achieve the desired quality, total quality management relies on statistical process control tools, quality circle, Six Sigma, diagrams, and graph analysis. Statistical process control (SPC) is a method that employs statistical methods to monitor processes and identify common causes of variation, whereas quality circles refer to a group of workers who to the same or similar work and meet regularly to analyze and solve work-related problems. Six Sigma comprises a set of techniques and tools for recognizing the causes of common variation in a process. It measures the probability of defects per million parts. Total quality management (TQM) is a lean manufacturing tool for organizational management that focuses on quality in order to improve customer satisfaction (Amasaka 2014). TQM is used to integrate commercial operations and create products or services with the highest possible quality. To be successful in the future, global traders must develop excellent quality management systems that can impress consumers and continuously generate high-quality products and services for the twenty-first century (Amasaka 2008).

6.4.1.2 Just in Time (JIT)

Just in time is a production philosophy initially developed for Japanese companies after the Second World War. The goal is to attain a competitive strategy, reduce production lifecycles, increase flexibility and product quality, and minimize costs. The basic principle of this philosophy is that materials are received only when they are needed in the production process, thereby reducing inventory costs. Just in time is also viewed as a production approach that emphasizes on the importance of continuous improvement at each supply chain stage from inter- and intra-organizational perspectives (Olhager and Prajogo 2012; Shah and Ward 2007). JIT seeks to increase customer satisfaction and is a key tool for operational and financial performance. Companies that implement JIT are able to respond to customer needs, promote perfect production activities, have high-quality products, make on-time deliveries, and minimize costs (Amasaka 2008).

JIT can be applicable in a broad range of industries and is a strong motivation to evaluate the performance of manufacturing industries in this book. Additionally, this philosophy integrates supply chain functions of marketing, distribution, customer service, sales, and production in controlled processes that eliminate waste, simply processes, reduce setup times, control the flow of materials, and emphasize on maintenance as a way to improve supply chain management. A just-in-time system tries to maintain a stable flow of materials by requesting only what is needed when it is needed (Galloway et al. 2012; Schoenherr and Swink 2012). Just in time is one of the pillars of lean manufacturing and is essential for improving business performance, through delivery times, for example (Danese et al. 2012).

6.4.1.3 Maintenance

The goal of any maintenance system is to prevent machine stoppages and keep the equipment in optimal conditions. Its main characteristics are the elimination of pollution sources, equipment cleaning and inspection, cleaning standards, maintenance training, and work environment control and management. Maintenance programs are usually approached from a Total Productive Maintenance (TPM) philosophy throughout the life of the production equipment. TPM engages operators to improve equipment effectiveness with an emphasis on proactive and preventive maintenance. Its main goal is the rapid improvement of production processes to reduce failures and the integration of machine and equipment with operators (Konecny and Thun 2011).

A TPM program is a comprehensive improvement program that emerged from TQM's concept of zero defects and aims at managing equipment performance (Seth and Tripathi 2005). The goal of any TPM program is to maximize production system reliability by maximizing machine and equipment effectiveness. In their work, McKone et al. (2001) analyzed the relationship between TPM and business performance using adjusted production as a mediating variable. The results indicated that TPM has a positive impact on costs, quality, and delivery times.

Also, because maintenance programs are supported by TQM, before implementing a lean production approach, both TPM and TQM must be implemented together, not apart.

Speed should be another attribute of maintenance programs. The implementation of TPM allows companies to reduce setup times, thereby generating more benefits. In this sense, single minute exchange of die (SMED) is another important tool (Chiarini 2014). It was developed by Shingo (Shingo and Dillon 1989) as a proposal for eliminating bottlenecks at car body-molding presses at Toyota. In the past, these machines did not work at their full capacity; thus, companies could not obtain the desired benefits. As Ulutas (2011) claims, nowadays, SMED is one important lean tool for reducing waste in the production process, since it is efficient in reducing exchange times in machines (Díaz-Reza et al. 2016).

TQM, JIT, and TPM strive to maintain a continuous improvement and increase organizational performance (Cua et al. 2006). By combining these techniques, companies can develop an integral and solid set of manufacturing practices that improve business performance. For this reason, many manufacturers focus on a simultaneous implementation of these programs in order to attain a synergistic effect. Many studies on TQM, JIT, and TPM explore improvement programs and their relationship with performance (Agus and Hassan 2011; Danese et al. 2012; Digalwar et al. 2015; Seth and Tripathi 2005; Teeravaraprug et al. 2011; Topalović 2015).

6.4.1.4 Advanced Manufacturing Systems

Gunasekaran (1999) discusses the need for manufacturing companies to be flexible and adapt to changes in market conditions through flexible manufacturing. Similarly, the author argues that in order to plan and manage their operations, firms should rely on effective support systems, such as material requirements planning (MRP), computer-aided design (CAD), computer-aided engineering (CAE), and enterprise resource planning (ERP). These technologies, when combined, reduce product design time and increase agility. Moreover, using the computer as a way to manufacture and train operators increases their potential. Unfortunately, traditional and less developed manufacturing industries tend to pay little attention to the power of advanced manufacturing systems and information technology.

Production processes can be classified according to the degree of automation and sophistication of control systems. The classification ranges from manual production to the use of computer-integrated manufacturing. In general, we refer to flexible manufacturing system as a production system made up of machines and subsystems linked by a common transportation and control system, with the ability to perform multiple tasks without changing the equipment in the system, thereby allowing for flexibility (Vallejo 2011). We will not discuss flexible manufacturing systems in detail, since this book considers the application of any of the following systems in the manufacturing industry as lean tools.

Flexible manufacturing systems are classified in five:

- Numerical Control Machine (NCM): It has its own numerical control and includes a feeding system and an automatic tool change.
- Transfer: It comprises a set of machines with a transportation system and a sequence of activities. It generally uses programmable logic controllers (PLC).
- Flexible manufacturing cell: comprises a few computerized numerical control machines for the exchange of machinery parts, as well as a central computer that coordinates activities, storage, and transport.
- Flexible production lines: an arrangement of machines or flexible cells that are interrelated thanks to a transportation system, which includes inspection. Flexible production lines use computers for production control and monitoring.
- Fully automated company: They have a series of flexible manufacturing lines and robot-automated warehouses. Everything is computer managed, including the planning of production, sales, and orders, among others.

To conclude this section, it is important to highlight that the goal of any manufacturing practice and its implementation should be to improve the production system through productivity and customer satisfaction. This book only considers four manufacturing practices to not distort the scope of our research, and because we believe they are the basic tools for an internal management of production processed and product quality.

This section discusses four manufacturing practices, selected from a literature review because of their relevancy as supply chain performance impact factors (Alcaráz et al. 2015; Amasaka 2014; Danese et al. 2012; Díaz-Reza et al. 2016; Digalwar et al. 2015; Teeravaraprug et al. 2011). Below, we list the attributes of these manufacturing practices, which will be used in subsequent chapters to assess the degree of implementation of such practices.

Total Quality Management (TQM)

- the company continuously implements statistical process control.
- the company frequently performs quality audits.
- the company frequently implements Six Sigma in processes.

Just-in-Time (JIT) System

- the company implements the just-in-time philosophy in all manufacturing processes.
- the company continuously seeks to minimize inventory levels.

Maintenance

- the company relies on preventive and predictive maintenance programs.
- the performance of preventive and predictive maintenance programs is effective.
- changes in processes are effective and efficient.

Advanced Manufacturing Systems

- the company makes effective use of computer-aided design (CAD), computer-aided engineering software (CAE), and computer-aided manufacturing software.
- the company uses flexible manufacturing systems.
- the company maintains communication with all its supply chain members through information systems.

6.5 Regional Aspects of the Supply Chain

6.5.1 Overview

The role of business location on performance is a topic of great interest. The location models so far proposed in supply chain contexts have had fruitful and fascinating applications (Melo et al. 2009). Multiple studies have attempted to explain the impact of business location on trade conditions, new production systems, technology development, manufacturing capabilities, and global networks (Cedillo-Campos and Sánchez-Ramírez 2013; Krumm and Strotmann 2013). Aspects such as land cost, taxes, infrastructure, urbanization levels, traffic, export tariffs, industrial concentration, employment levels, and the degree of tertiarization (managed about thirty parts) have all been taken into account to analyze industrial growth (Bhatnagar and Sohal 2005; Cirtita and Glaser-Segura 2012).

A good transport infrastructure for all modes of transport is a key to competitiveness and therefore has an impact on decisions related to a business's location. Quantitative factors in location analysis usually include: perception of land costs, energy, transport infrastructure, business services, workforce, and telecommunications (Arent and Steinbrecher 2010). A strategic supply chain design anticipates the problem of quantity, location, and capabilities for manufacturing, assembly, and distribution, which affect the flow of materials, inventory levels, and the mode of transport to be selected (Melo et al. 2009).

For their location, companies also take into account what other countries have to offer (e.g., production capabilities and development and research opportunities) and the very specific characteristics of each firm (technological competence, workforce, size, and organizational structure) (Nachum and Wymbs 2005). Infrastructure quality, workforce, and regional growth are also crucial (Farrell et al. 2004), whereas the accessibility of the location and the incentives might be less decisive. Some studies conclude that global manufacturing networks depend on what other countries offer them as potential locations for their businesses (e.g., infrastructure and human resources) than on costs (taxes and transportation costs).

Business location has become a strategic decision in modern supply chain environments. This decision involves the irreversible allocation of capital and often has as a crucial impact on key supply chain performance measures. Administrators must appropriately evaluate the potential of a given location in terms of its impact on operational performance. Such evaluation must be performed without underestimating potential risk sources in production processes, demand, and supply (Bhatnagar and Sohal 2005) and by taking into account both qualitative and quantitative aspects that can eventually explain the level of performance attained. To Ferdows (1997) locating a business abroad just to take advantage of preferential tariffs, cheap workforce, subventions, and cheap logistics costs is not enough, since companies do not take advantage of the potential of their processes. Companies should use their businesses settled abroad to approach local customers and suppliers and attract qualified human resources, all this in order to contribute to the company's performance.

Studies that explore the impact of location decision have tried to explain the impact of global trade conditions, new production systems, and new technologies. Likewise, scientists and experts have proposed strategic planning models and have emphasized on the fact that a global logistics network must reflect transportation costs, labor costs, infrastructure, the overall business's environment, proximity to other markets and suppliers, taxes, and strategic alliances (Schmidt and Wilhelm 2000). Other models have associated production, location, and distribution decisions with exchange rates and tariff rates (Bhutta et al. 2003) or studied the impact of foreign investment on five variables: population, wages, GDP, economic stability, and cultural attributes (Sethi et al. 2003). Similarly, the literature reports the study of location decisions in the automotive industry with respect to a country's competitive advantage. The model in question found a significant relationship between a country's level of competitiveness and the success of a company established in it.

Among those research works that discuss Porter's competitiveness model, some have demonstrated that, with a few modifications, the model can be used for strategic location planning, which is interesting because the model could adapted to a given region, depending on that region's competitiveness indicators. From a different perspective, researchers have developed statistical models to demonstrate that product differentiation is a key element to location decisions. That is, proximity and differentiation are associated with the type of industry and the type of product to be developed (Nachum and Wymbs 2005).

Table 6.5 lists some of the research works that explore location decisions and business location as such. As can be observed, these works mainly employ mathematical modeling and optimization models for location decision, considering infrastructure and incentives (Farrell et al. 2004), production and distribution channels (Bhutta et al. 2003), or even product design, product differentiation, and organizational structure (Nachum and Wymbs 2005). Similarly, other works focus on strategic planning for business location (Lee and Wilhelm 2010; Moon 2005; Schmidt and Wilhelm 2000), and other researchers have conducted multiple literature reviews to identify the most common location decision problems (Farahani et al. 2012).

Table 6.5 Regional attributes reported in the literature

Author	Attribute (element)	Approach
Schmidt and Wilhelm (2000)	Strategic planning	Descriptive analysis
Sethi et al. (2003)	Foreign investment	Linear regression
Bhutta et al. (2003)	Location, production, distribution	Mathematic
Farrell et al. (2004)	Location, infrastructure, incentives	Mathematic
Nachum and Wymbs (2005)	Product differentiation	Statistic
Bhatnagar and Sohal (2005)	Location, competitiveness	Linear Regression
Moon (2005)	Strategic location selection	Descriptive analysis
Kim and Kim (2005)	Localization, automotive sector	Linear regression
Bogataj and Bogataj (2007)	Location	Linear programming
Melo et al. (2009)	Location	Operation research
Lee et al. (2009)	Location, supply chain management	Descriptive analysis
Lee and Wilhelm (2010)	Location, strategic planning	Literature review
Bogataj et al. (2011)	Location, global supply chain	Mathematic
Farahani et al. (2012)	Location	Literature review
Krumm and Strotmann (2013)	Location, regional factors	Linear regression

Source Avelar-Sosa et al. (2014)

The methodologies on which these works rely are varied, yet most of them are qualitative or quantitative analyses. This trend presents an area of opportunity, since as Bhatnagar and Sohal (2005) argue, “it is impossible to ignore qualitative aspects in performance measurement.” In this sense, in any location decision, firms must consider qualitative elements and their impact on supply chain through location factors of a given region, city, or country. Under this premise, regional aspects are key to obtain short-term benefits. In this book, we consider the aforementioned works to identify the influence of regional factors on companies.

Even though there are many methodologies for studying business location, the use of structural equation modeling is relatively scarce. The studies identified in the literature analyze location decision factors by considering both the company’s own characteristics and externalities of the environment to be chosen. In order to explore the impact of these externalities on company performance, this book takes into account seven external attributes found in the literature—regional infrastructure, costs, services, government, market proximity, and workforce.

6.5.1.1 Regional Infrastructure

Infrastructure is the set of facilities, services, and goods provided by the government for companies to work effectively. Infrastructure does not only comprise transport and telecommunications but also all legal and public activities. A poor infrastructure implies external trade costs for supply chain actors. Also, infrastructure refers to the availability of transportation and telecommunications services, which improve and streamline business operations, or even to those services offered locally with respect to those of other regions. The role of infrastructure was first addressed by classical economics literature, where authors defended the importance of making substantial investments in infrastructure before investing in anything else.

Whether infrastructure has a positive or negative impact is an empirical, and therefore crucial, question for all countries in light of the economic development that is sought nowadays. The study of infrastructure began in the USA in the 1970s, when experts wondered whether productivity stagnation was due to a decrease of infrastructure investment. Eventually, it became important to analyze institutional quality and characteristics in order to identify their importance in and influence on cost effectiveness, thereby proposing a new explanation to the relationship between infrastructure and economic growth (Calderón and Servén 2004; Shi et al. 2017).

To evaluate the infrastructure of a place, Shi and Huang (2014) first suggest knowing about the different types of infrastructure, which include: electricity, roads, railways, and telecommunications, measured in physical units. Then, to the authors, it is important to understand that investing in infrastructure implies long-term planning and offers durability. The study promises long-term effects using a vector error correction model. Finally, Shi and Huang (2014) argue that there should be an optimal interaction between infrastructure capital and private capital, both domestic and foreign. This interaction can be found in an analysis that considers the production function.

Country-specific studies focus on different types of infrastructure. For instance, Röller and Waverman (2001) analyzed the telecommunications infrastructure in 21 OCDE countries, while Duggal et al. (2007) evaluated the United States' technology infrastructure, and (Gonzalez-Navarro and Quintana-Domeque 2010) studied Mexico's road infrastructure and pavement. All these infrastructure aspects are a part of a logistical integration and are key to the productive integration of companies. Without a proper and efficient interconnection between infrastructure networks and services, it is impossible to generate value chains and create overall productivity. The role of the transportation industry in modern trade environments is unquestionable. It is generally agreed that a solid and high-quality transport infrastructure promotes sustainable growth and significantly contributes to closing inequality gaps (Perrotti and Sánchez 2011). The lack of an appropriate transport infrastructure and efficient provision of its services are obstacles to social development policies, sustainable economic growth, and territorial integration (Rozas and Sánchez 2004). In this sense, the role of a region's infrastructure must be oriented toward productivity development, both in the present and in the future. In parallel, political, human, and social policies must be implemented to support this development.

6.5.1.2 Regional Costs

Production costs are those incurred by the company in order to produce goods or services; they include raw material costs, labor costs, service costs, and indirect costs. Raw material costs refer to the value of the raw materials used in the production process, whereas labor costs is the sum of all wages paid to employees. On the other hand, service costs are those incurred from employing independent contractors to perform tasks that are necessary for production. Finally, indirect costs are expenses that are not directly associated with the production (Rincón and Fernando 2016). Logistics service costs can adversely affect the economic benefits of supply chains. They refer to those incurred by companies and organizations in order to guarantee a given level of service to both customers and suppliers. They include supply expenses, distribution costs, transportation costs, inventory costs, storage costs, supply-related costs, order processing costs, and general and administrative (G&A) expenses. G&A expenses represent the necessary costs to maintain a company's daily operations and administer the business. They include rent, utilities, water supply services, electricity supply services, and security and surveillance services, among others (Estrada Mejía et al. 2010).

6.5.1.3 Services

Services and their quality have a close relationship with infrastructure, since they are a part of it. Services connect supply chain actors both physically and virtually in a landscape of global production and trade. Because of their characteristics and the infrastructure, services promote territorial, social, and economic connection and have the potential to improve connectivity, minimize transportation costs, and improve the logistics chain in general, thereby improving competitiveness and trade activities. Likewise, services facilitate social development by integrating and connecting regions and allowing people to connect with their environment. Services are important for production and life quality improvement (Rozas and Sánchez 2004).

6.5.1.4 Government

Government support is one of the driving forces of change and shapes the economic and political landscape of any country or region (Coyle et al. 2013). Governments establish policies, regulations, and tariffs that undoubtedly impact businesses and supply chains. For instance, regulations are established in transport, communications, and financial institutions. Moreover, they are the pillars of infrastructure in many organizations. Similarly, transportation costs minimization policies are only effective if regional political actions strive to provide the region with the necessary human capital in order to improve the business environment and thus encourage capital investment and skills concentration (Sánchez-Reaza 2010).

Government support is a key ingredient when the business demands market updating and globalization. To gain access to global markets, business environments should attract new companies or connect existing ones with global production chains (Woodward 2009). Public policies for trade and industrialization promote economic growth in any country or region that includes aspects of equity, efficiency, and coordination. In this sense, vertical coordination across government levels is not only desirable but also indispensable (Sánchez-Reaza 2010).

6.5.1.5 Quality of Life

The concept of quality of life emerged in the USA after the Second World War to refer to the people's perception on their life and financial security. The notion expanded after the 1970s when social scientists collected data on people's socio-economic and educational levels and living standards, which were often low (Bognar 2005). The concept of quality of life originated to distinguish relevant results in healthcare research (Urzúa and Caqueo-Urízar 2012) and demands an objective evaluation of a person's health, physical environment, income, housing, and other observables and quantifiable indicators (O'Boyle 1994). A general definition of quality of life would be living well and with the hope of living even better, according to the principles of personal dignity, solidarity, distribution of goods and wealth, work, and adherence to good values (Brugarolas 2017). Based on this definition, we consider quality of life as those aspects that a region has to offer for people to do their jobs in acceptable conditions and have a dignified life.

6.5.1.6 Proximity

Physical proximity among upstream and downstream companies facilitates information sharing and promotes a continuous exchange of ideas and innovation. In his study about systemic competitiveness, Porter suggests what he calls the mesolevel, which refers to the level of competitiveness generated through policies that encourage the development of specific structures and support for leading national companies. The mesolevel considers competitiveness at a regional and national scale. Because companies do not compete individually, but rather as supply chains, market proximity is a competitive strategy for maintaining a good relationship with suppliers of knowledge and technology. Market proximity generates benefits through three fundamental conducts: availability of qualified workforce, knowledge diffusion, and availability of intermediary goods. Also, market proximity reduces the price of the final product as a result of low transportation costs (Spiekermann et al. 2011). Geographical proximity promotes face-to-face contact between firms and facilitates interpersonal communication among supply chain members, thereby increasing reliability and trust (Ganesan et al. 2005).

6.5.1.7 Workforce

This factor comprises all the characteristic of people living in a specific region. Human resources' characteristics greatly vary across regions and therefore have an impact on the operational performance of manufacturing companies. Through the quantity, quality, or availability of educational institutions, companies hire different degrees of qualified workforce. Human resources must be capable of performing their jobs in the company thanks to their education, abilities, training, and personal skills.

The aforementioned six aspects can assess the regional factors that have an impact on supply chain behavior and benefits. These elements were selected for this book after a careful review of the literature (Bhatnagar and Sohal 2005; Su and Yang 2010). These six aspects, through their corresponding attributes, can help explain how manufacturing companies perceive the environments where they operate. The attributes of each regional factor can be listed as follows:

Regional Infrastructure

- The available land, energy, transportation system, and telecommunication systems facilitate the company's economic development.
- If compared with other regions, the quality of telecommunications and the transport infrastructure allow the company to run properly.
- Internet availability and quality improve the operations of the company.
- Services in the industrial parks give the company operational competitiveness.

Regional Costs

- Land and infrastructure costs make the company more competitive.
- Labor costs make the company's operations competitive.
- Telecommunications costs do not interfere with the company's competitive strategy.
- Public service costs do not exceed estimations.
- Private services costs (banks, transport companies, legal and accounting offices) are low.

Services

- Services availability and information technologies allow the company to operate properly.
- Services quality allows for the continuous improvement of operations.

Government

- The support granted by the city council facilitates the operations.
- The support granted by the state's government facilitates the operations.
- The support granted by the federal government facilitates the operations.
- Protection protocols for foreign investment are adequate.
- Administrative efficiency and transparency facilitate operations.

Quality of Life

- The quality of life in the region is favorable.
- The availability and quality of education in the region are adequate and sufficient.
- The availability and quality of healthcare services are sufficient.
- The region's environment benefits personal growth and development.

Proximity

- Supplier availability and proximity is adequate and reliable.
- Competition in the region promotes innovation in the company.
- Market proximity increases the company's competitiveness levels.

Workforce

- The level of education and skills of the people match those required by the company.
- Availability of engineers, executives, and operators is enough for the company to run properly.
- The experience and competence of the people allow companies to attain their short-term goals and policies.

These attributes will allow us, in further chapters, to assess the perception of the sample on the regional aspects that characterize the environment of the surveyed companies and to determine which of them a key to competitiveness and profits are. Similarly, these attributes will help us identify what kind of support the government actually offers manufacturing companies and the perception of the sample on the impact of this support on supply chain performance and benefits.

Finally, to conclude this chapter, it is important to keep in mind that a wide range of risk factors, regional factors, and manufacturing practices can be associated with supply chain performance and hence competitiveness. The assessment methodologies for these impact factors are also varied. This book addresses supply chain performance impact factors as suggested by (Bhatnagar and Sohal 2005) along with the characteristics of the surveyed industrial environment to explore their influence on supply chain performance.

Manufacturing companies compete with each other to gain the desired competitiveness and have become important links of global production chains. Since global market exigencies are more challenging over time, it is important to assess a firm's internal and external activities, because supply chains comprise a wide range of companies, from suppliers to financial companies, to transportation companies, to name but a few. This level of complexity can compromise an appropriate supply chain management approach. We believe that it is impossible to be competitive when controlling only a business's internal aspects, since physical elements, such as regional infrastructure and location, also have an impact on the performance and competitiveness of a supply chain. For Mexican manufacturing companies, there is a particular external impact factor: the country's proximity to the USA.

In order to know whether companies are appropriately managing their supply chains and actually gain the expected benefits, we need to take into account the activities they perform jointly in the three factors: risks factors, regional factors, and manufacturing practices. The attributes of these factors, which are briefly listed in this chapter, will be further explained in subsequent sections in terms of their structure and their role as supply chain performance indicators.

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Chapter 7
Supply Chain Performance Attributes and Benefits in the Manufacturing Industry

7.1 Overview of Supply Chain Performance (SCP)

In a modern competitive global marketplace, organizations have been forced to modify their work approaches in order to increase customer service levels, while simultaneously dealing with the pressures to reduce operating costs and ensure deliveries on time. In doing so, companies have adopted new forms and systems for measuring performance (Wang et al. 2017). The operations management and supply chain management literature report the importance of integrated performance measurement systems to improve decision making (Ramaa et al. 2013). Recently, supply chain management (SCM) became a popular strategy for efficiency measurement and cost reduction (Aksoy and Öztürk 2011). In fact, 70% of the price of a final product comes from the costs of raw material.

Supply chains have become the focus of considerable attention around the world, making it possible to determine their efficiency and performance measures. To this end, experts have tested models of independent variables and controllable activities within companies. Increasing efficiency in production processes has allowed companies to minimize costs, improve product quality, and streamline operations. In this sense, companies seem to rely more and more on convenient performance evaluation strategies that imply identifying attributes and controllable variables that can mitigate risks in supply, demand, and production processes.

From a management perspective, modifying the structure of a supply chain system means to incorporate a competitive strategy. Companies manage everything that allows them to integrate their supply chain and operate better. In this sense, improving performance also implies flexibility, information availability and quality, and better transportation systems. Following the example of Toyota and Walmart, many companies around the world seek to improve manufacturing practices throughout the chain to achieve more benefits and greater competitiveness (Fernández et al. 2015).

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Performance is a way to measure organizational strategies in different processes. Moreover, it allows companies to achieve their goals through the implemented strategies. The different performance outcomes are the result of the behavior, desires, motivation, values, and interests of those people directly involved in the company's operations (Pérez and Cortés 2009). A supply chain encompasses various organizations, also known as supply chain partners, such as suppliers, manufacturers, carriers, distributors, or wholesalers, among others. They are all involved in the production process through the flow of materials, information, and money. Conversely, SCM includes all the activities that must take place to deliver the right product to the right customer in the right quantity and at the right time (Seuring 2013). SCM deals with all the supply chain activities—planning and forecasting, purchasing, product assembly, moving, storage, distribution, sales and customer service (Melo et al. 2009)—and its goal is to minimize total costs while value is delivered.

7.2 Concept of Supply Chain Performance

Chapter 5 addressed the concept of supply chain performance (SCP), its indicators, benefits, and implications. Similarly, we discussed competitiveness as the result of supply chain improvement strategies. This new section defines the concept of supply chain performance according to several authors. The goal is to find the performance attributes studied in this work. SCP has been defined as a systematic process of measuring the effectiveness and efficiency of supply chain operations (Anand and Grover 2015). Supply chain performance is the ability of the supply chain to provide products and services of appropriate quality in specific quantities and at the appointed time and minimize the total cost of products and services to the final customer in the supply chain (Whitten et al. 2012). To others, SCP is the ability of supply chain systems to deliver the right product, in the right place, at the appropriate time, and at the lowest logistics costs (Zhang and Okoroafo 2015). In other words, all the definitions take into account delivery times, costs, and value for the end customer. Likewise, it is possible to set three basic criteria for SCP (Estampe 2014):

- Efficacy: It is the relationship between the achieved results and the pursued objectives.
- Efficiency: It is the relationship between the efforts and resources involved in the operation and the actual utility value.
- Effectiveness: It is satisfaction with results.

For other authors, SCP is a systematic process to measure the effectiveness and efficiency of supply chain operations (Anand and Grover 2015) that also promotes collaborative integration between all members. According to Constangioara (2012), SCP can be measured in four areas: customers, operations, innovation, and financial performance. These areas include measures such as sales profit margin, speed of delivery, flexibility, capacity, and ICT implementation, among others, with respect to financial and organizational performance.

Multiple supply chain performance indicators have been proposed throughout the years, so each company selects those that best fit its objectives and scope. Some authors propose six categories of SCP indicators: quantitative and qualitative, financial and non-financial, and economic and operational (Ilkka 2015; Leończuk 2016; Maestrini et al. 2017). These categories were thoroughly discussed in Chap. 5 (see Table 5.3), which also determined other indicators, such as costs, quality, flexibility, resources utilization, trust, and delivery times, among others. The following section thoroughly describes these SCP indicators and determines those to be used in subsequent chapters.

7.3 Attributes for Supply Chain Performance Measurement

Performance is measured with respect to certain attributes to determine whether the operational activities in a company are well executed. However, these attributes also analyze supply chain outcomes. SCP parameters are a set of parameters used to determine the efficiency and effectiveness of an existing supply chain system or to compare competing alternative systems. A wide range of parameters, both qualitative and quantitative, are reported in the literature. Qualitative SCP measurement is performed through attributes such as customer satisfaction, information integration, material flow integration, and risk management performance. On the other hand, quantitative SCP measurement includes measures such as cost minimization, sales and profit margin maximization, and inventories and lead-time reduction, among others. Sometimes, experts also rely on forecast accuracy, delivery time capabilities, delivery reliability, and fast response to customer responsibility (Qrunfleh and Tarafdar 2014).

Performance reflects how companies improve to achieve their objectives, mission, and values. In the literature, this concept is reported as corporate performance and can be measured through aspects such as return on assets, sales growth, productivity and time cycle, quality, inventory performance, and financial liquidity. In other words, corporate performance is mostly measured through financial indicators (Gawankar et al. 2013). In this sense, Ganga et al. (2011) suggest the following five performance attributes:

- Reliability: The right product is delivered in the right place, in the right amount, at the right time, with the precise documentation, and to the correct customer.
- Responsiveness: The speed of the supply chain to provide products to its customers.
- Flexibility: The agility of a supply chain to respond to demand changes, and to gain or maintain its competitive advantage.

- Costs: All those expenses incurred in operating the string.
- Asset management efficiency: The efficiency of an organization in managing its resources to meet the demand.

In their work, Carvalho et al. (2012) propose two SCP performance dimensions: economic and operational. The former includes cash flow cycle, added economic value, costs, return on assets, and efficiency in the chain, whereas the latter comprises quality, delivery time, flexibility, the efficiency of the cycle, and inventory levels. That said, this book considers the following attributes for supply chain performance assessment: delivery times, quality, flexibility, agility, customer service, transportation, and inventory. The following sections thoroughly discuss each one of these indicators.

7.3.1 Agility

The concept of agility originated in the manufacturing sector in the early 1990s as a strategy to respond more effectively to a changing competitive landscape. Some authors define it as the ability to customize products to fit production volumes, respond to changes in delivery requirements, and produce a certain range of products (Li et al. 2009). For others, agility is the ability of a company to rapidly adjust tactics and operations within their supply chain and respond or adapt to changes, opportunities, and threats in their environment (Gligor et al. 2013). From a corporate vision, agility is the successful exploration of competitive bases (speed, flexibility, innovation proactivity, quality, and profitability) through the integration of reconfigurable resources and best practices in a knowledge-rich environment to provide customer-driven products and services in a fast-changing market environment (Gligor and Holcomb 2012). Taking the tenets from both streams, we can define supply chain agility as an operational and relational capability in quick response to uncertain and turbulent markets.

Agility is the strategic capability that helps organizations to detect and respond quickly to internal and external uncertainties through the effective integration of the relationships in the supply chain (Fayezi et al. 2015). Some elements that contribute to the improvement of agility are information, communication, and coordination through information systems, infrastructure, and availability of logistics services. Similarly, according to Swafford et al. (2008), supply chain agility comprises the following requirements:

1. Speed in reducing manufacturing lead-time
2. Speed in reducing development cycle time
3. Speed in increasing frequencies of new product introductions
4. Speed in increasing levels of customization
5. Speed in adjusting worldwide delivery capability

6. Speed in improving level of customer service
7. Speed in improving delivery reliability
8. Speed in improving responsiveness to changing market needs.

In conclusion, agility is a prototype that promotes proactivity, responsibility, proper use of information technologies, speed, adaptability, flexibility, and cooperation among all supply chain partners (Tseng and Lin 2011).

7.3.2 Flexibility

Flexibility has been studied for years, but today is a crucial issue that should not be left aside when improving performance in supply chains. Multiple works have evaluated, measured, and/or contextualized flexibility, especially to find the best way to relate it to supply chain performance. Flexibility is commonly defined as the operational skill that enables organizations to efficiently change their operations to respond to internal and external uncertainties in the supply chain (Fayezi et al. 2015). According to Boulaksil et al. (2011), flexibility is the ability of a business process to effectively manage or react to changes with little penalty in time, cost, quality, or performance.

Flexible supply chains must be able to adapt effectively to supply chain disruptions and changes in demand while maintaining customer service levels (Kumar et al. 2008). The improvement of the most important factors gives greatest contribution to the system flexibility (labor flexibility, machine flexibility, routing flexibility). Flexibility in supply chain focuses on maintaining customer service levels and adapting to disturbances in supply and sudden changes in demand (Huaizhen et al. 2009; Kumar et al. 2008).

Supply chain flexibility refers to the speed and quickness at which companies can respond to changes throughout the entire chain in relation to competitors. Flexibility can be a proactive attribute designed in a system and a more reactive behavior (Naim et al. 2006). As a result, companies see their supply chain partners as sources of flexibility that help them improve the performance of internal operation. Malhotra and Mackelprang (2012) argue that flexibility in the chain must be a complete system. Not only must it be detailed how flexibility will be included in the string, but also how to measure it.

Improving flexibility and agility in supply chain is crucial to current environment of globalization and competitiveness. Therefore, it implies assessing the elements that adversely affect supply chain performance. Some elements studied by researchers as sources of flexibility are the levels of infrastructure and logistics services in certain geographic regions. For instance, competitive transportation depends on infrastructure, which includes not only road transport accessibility, railway, seaway, and airway, but also the perception of costs for land, energy, transport services, business services, and telecommunications (Arent and Steinbrecher 2010; Grek et al. 2011).

7.3.3 Customer Service

Overall, services are activities that can be perceived but not touched. They are the reason why servers and customer interact. In most companies, customer service is defined in three different ways (Samii 2004): as an activity; as a performance measurement; and as a philosophy and strategic element of the company. The definition of customer service varies from one company to another. Customer service is a process which takes place between the purchaser, the salesperson, and the intermediaries. This process leads to added value for the service produced or exchanged.

Multiple works are intended to understand and explore what customer service is and entails. For instance, Perez (2014) claims that customer service encompasses those activities that relate attitudes that are designed for the needs of users. The word service comes from the verb to serve that refers to being available to others. Similarly, service is a set of activities that seek to respond to one or more needs of a client. On the other hand, Montoya and Saavedra (2013) define customer service as that set of actions that a supplier provides to its clients. Customer service is achieved by improving various aspects that satisfy customer needs. It is also referred to as added, intangible value that is decisive in customer loyalty (García 2016).

Morillo (2009) suggests that customer service is a set of interrelated activities that a supplier provides with the purpose that customers obtain a product at the time and place and to ensure its correct use. Finally, other authors conceive customer service as a diagnosis that should always be performed in the company toward the needs and tastes of the customer, since it allows the company to gain market positioning (Aguilar and Vargas 2010). Customer service is not a product but a process; therefore, it cannot be standardized and might be harder to control accurately. In this sense, the authors propose seven features to distinguish customer service from other performance metrics:

- It cannot be stored or accumulated.
- Unlike products, it cannot be monitored.
- It is impossible to previously establish its final quality.
- Information is the basis of the process.
- They are not permanent. They end at the time of consumption.
- Staff that produces the service comes into contact with the user.
- Workers are responsible for the information.

7.3.4 Delivery Times

Delivery times are the link in a supply chain that directly impacts customers. It is a primary determinant of customer satisfaction; hence, measuring and improving delivery are always desirable to increase competitiveness. Delivery by its very nature takes place in a dynamic and ever-changing environment, making the study and subsequent improvement of a distribution system difficult (Gunasekaran et al. 2004). On-time delivery reflects whether perfect delivery has taken place or otherwise and is also a measure of customer service. Delivery time is a measure of supply chain performance that is characterized by punctuality and reliability of the delivery of the product to the end customer. It is recognized as a key indicator of operational performance (Bushuev 2018). In short, delivery process time is the time required to perform a process or set of activities within the supply chain. Similarly, it is referred to as the time needed to produce a product, from the time the customer places the order until it is delivered.

7.3.5 Quality

According to Cuatrecasas (2012), quality is the set of characteristics of a product or service obtained in a productive system, as well as the ability to satisfy the user's requirements. It is therefore important that all the people involved in the process are competent, trained, and committed to generating value (Hahn 2012). Similarly, quality is usually seen as a dynamic state associated with product, services, people, processes, and environments that meet customer needs and expectations (Goetsch and Davis 2014). Quality must be directed toward the needs of the client, both in the future and in the present. It must not be forgotten that the continuous improvement of quality covers all the production process, from small but indispensable materials, to the consumer and the redesign of the product or service.

Quality management philosophies endeavor not only to consistently satisfy or exceed customer expectations, but also to meet the expectations of those parties that are important for the continuity of the business (e.g., public organizations, regulatory bodies, suppliers, shareholders). Siva et al. (2016) highlighted the role of quality management in the sustainable development of organizations and recommended the implementation of quality tools and techniques to facilitate business sustainability improvements. In this sense, it has been claimed that companies must incorporate supply chain and quality management practices to achieve higher levels of customer satisfaction through enhanced collaboration within their network of firms, as well as higher performing processes that ultimately reflect on higher quality products and services (Robinson and Malhotra 2005).

Manufacturing industries are at the forefront of quality management, supply chain, and sustainability integration research. Most of the empirical studies focus on the organizational developments in manufacturing-orientated sectors, such as the automotive, chemical, and electronics sectors. This trend reflects the inherent pressures on the manufacturing industries for higher performing, cleaner, and more responsible products, services, processes, and supply chains (Cherrafi et al. 2016). Practices such as continuous improvement improve organizational performance (Fernandes et al. 2016). Therefore, supply chain performance is highly enhanced through quality principles and continuous improvement concepts that are deployed across the supply chain network (Terziovski and Hermel 2011). Consequently, it is important to consider the quality of the products to assess the level of customer satisfaction and thus the associated benefits in the supply chains.

7.3.6 Inventory

Inventory management is one of most complex organizational functions, yet it is made more acute in emerging economies, where diverse factors are taken into account. Inventory management is fundamental for the survival of enterprises in modern times (Sucky 2005). Moreover, it is an important area of opportunity wherein organizations seek to reduce costs without reducing their income. Some authors consider inventory management a key factor to maximize profitability and minimize costs, while simultaneously meeting customer requirements (Toro and Bastidas 2011). Others, on the other hand, suggest that inventory management seeks to achieve two fundamental goals: (a) to give the level of service desired by the customer and (b) to have the lowest inventory costs. In this sense, delivery time variability plays a crucial role in inventory management (King 2011).

Some suggested metrics for managing initial inventory are tariffs, complete orders, returned goods, cancelation rates, inventory turnover, and return on investment (Izar et al. 2016). The new paradigm of inventories is an integral part of the value chain, closely related to other functions of the organization. Inventory management has become a strategic tool that achieves economic benefits and customer satisfaction (Chikán 2007). Inventory in the production process and finished product inventories constitute an aspect of great importance for companies, and they are a starting point for strategic decisions. Therefore, their management is necessary for the efficient marketing of goods and services (Hillier and Lieberman 2010).

7.3.7 Transportation

Governments and international institutions have taken interest in transport and logistics costs as two key elements of national competitiveness. Much of the flow of economic and social activities comes from transportations and logistics systems (Arvis et al. 2012). Transport and logistics are a conglomerate of businesses with their own technical and operational attributes, such as costs, capacity, efficiency, reliability, and speed. These attributes can assess economic growth. In their work, Smith et al. (2008) claim that the improvement of transportation systems is a critical element for successful business, communities, and social development, and they promote international competitiveness.

Other researchers point out that transport infrastructure is one of the most important indices of international logistic competitiveness. It includes variables such as capacity and average duration (Chow and Gill 2011). In short, a network of well-developed transport infrastructure is a prerequisite for accessing economic activities and services around the world (Zamora and Pedraza 2013). As discussed in the "Supply Chains, Transport and Competitiveness" report, issued by the United Nations Economic Commission for Europe, a lack of transportation competitiveness is the result of high costs and the transport infrastructure itself (road, railways, and ports. Nevertheless, transport is considered as one of the driving forces of economic growth and social development (Ojala and Hoffmann 2010).

On the other hand, the "Connecting to Compete: Trade Logistics in the Global Economy 2014" report, issued by the World Bank points out at six logistics performance indicators in terms of transport (Ojala and Celebi 2016):

1. Efficiency at customs and borders
2. The quality of trade and transport infrastructure
3. The ability of an organization to send products at competitive prices
4. The competence and quality of logistics services, transport, etc.
5. The ability to track and trace shipments
6. The rate of product deliveries.

In conclusion, in terms of supply chain management, transport is a key factor. An inadequate transport infrastructure and poor-quality transportation systems are an obstacle not only to supply chain performance, but also to adequate social development.

7.3.8 Financial Performance

Performance measures reflect how firms operate to achieve their objectives, mission, and values. Financial performance includes conventional measures of performance for a business unit (Feng et al. 2018). Firm performance is often measured using financial performance indicators such as profit, revenues, and return on investment (Gawankar et al. 2013). Financial and operational indicators measure the total cost of logistics operations, that is the monetary value of serving customers and planning, managing, acquiring, distributing and storing inventory for target customers.

Time indicators help companies control the duration of the logistic process, whereas quality indicators show the efficiency of the activities in the logistic process. Conversely, productivity indicators reflect the ability of the logistic process to efficiently use the assigned resources, such as workforce, storage spaces, vehicles, systems of information, etc. Finally, financial indicators highlight the economic, easily measurable consequences of actions that have already been performed. Measures such as sales growth, profit margin, and market share measure the financial performance of companies. Improving overall performance comes from improving investments in operational resources, efficiency, and marketing.

Better financial performance can also be achieved through cost minimization and resource utilization efficiency (Feng et al. 2018). Some attributes reported in the literature for firm performance measurement include return on assets, market share, return on investment, net profit, growth in net profit, sales, sales growth, productivity ratio, total cycle time, total cash flow time, cost saving, inventory turnovers, earnings before taxes, gross margin, quality performance, inventory management performance, and financial liquidity (Vikas et al. 2017). Similarly, there are non-financial measures, such as overall competitive position, present value of the firm, innovation performance, market share, and quality improvement.

The attributes used in this work to assess supply chain performance in the export-oriented manufacturing industry are listed below. These attributes were also used to analyze the perception of the respondents with respect to the operations that the surveyed companies perform.

Flexibility

- Setup times have improved in the last three years.
- Employment contracts are flexible.
- Employees have multifunctional skills.
- It is possible to rapidly adapt processes to the forecasted demand.
- It is possible to rapidly adjust inventory levels to the forecasted demand.
- Changes in products can be performed with agility.

Agility

- In the last three years, product development cycle times have been improved to reach target markets.
- The company effectively responds to unexpected demand.
- The company responds to the delivery requirements of customers.
- Product customization levels have been improved.

Customer service

- In the last three years, the company has delivered full orders.
- If compared to similar companies, the company has the best rate of complete orders.
- The company responds to customer needs in terms of time and costs.

Delivery times

- Products are delivered according to the just-in-time philosophy.
- The company delivers complete orders on time.

Quality

- Product quality meets the standards.
- Product quality is satisfactory (no customer complaints in the last three years).

Financial performance

– The company's market strategy focuses on total cost reduction.
– The cash flow has improved in the last three years.
– The sales growth rate has improved in the last three years.

Inventory

– Return on inventory has improved in the last three years.
– Return in inventory has been improved in the last three years if compared to that of the industry.
– The company has reduced inventory levels in the last three years.

Transportation

– Raw material and transportation costs are low.
– Satellite tracking systems have improved raw material and product deliveries in the last three years.
– Transportation quality has improved in the last three years thanks to authorized retailers and outsourcing.

7.4 Firm Performance

7.4.1 Overview

Performance measures reflect how firms operate to achieve their objectives, mission, and values. Financial performance includes conventional measures of performance for a business unit (Feng et al. 2018). Firm performance is often measured using financial performance indicators such as profit, revenues, and return on investment (Gawankar et al. 2013). The most common firm performance measures are return on assets, market share, return on investment, net profit, net profit growth, sales, sales growth, productivity ratio, total cycle time, total cash flow time, cost saving, inventory turnovers, earnings before taxes, gross margin, quality performance, inventory management performance, and financial liquidity (Gandhi et al. 2017).

Firm performance is usually measured through two dimensions, growth and profits. Profits are an indicator of efficiency, while growth is an indicator of the success of the company in the marketplace (Merschmann and Thonemann 2011). Advantages due to effective supply chain management and collaboration among supply chain partners include financial benefits, operational benefits (Fawcett et al. 2008), and environmental benefits (Feng et al. 2018). Some examples of these benefits are efficiency, cost, return on assets, economic added value, and cash to cash cycle. Some authors suggest that corporate performance is associated with business, operations, and customer service. Specifically, the performance of local companies can be evaluated by comparing its performance with that of its competitors in terms of (i) return on investment (ROI), (ii) profits as a percentage of sales, (iii) decreasing the product or service delivery cycle time, (iv) rapid response to market demand change, (v) rapid confirmation of customer orders, and (vi) increase in customer satisfaction (Liu et al. 2013).

As Hervani et al. (2005) indicate, corporate performance measurement continues to grow and encompasses both quantitative and qualitative measurements and approaches. The types of measures used depend greatly on the goal of the organization and on the individual characteristics of the business. However, it is important that companies consider existing financial measures, such as return on investment, profitability, market share, and revenue growth at a more competitive and strategic level. Other measures like customer service and inventory performance are more operationally focused (Hervani et al. 2005). The benefits of performance evaluation include assessing and controlling progress, highlighting accomplishments, improving understanding of key processes, identifying potential problems, and providing insight about possible future improvement actions, among others (Ahi and Searcy 2015). The truth is that such benefits are not always easy to achieve.

7.4.2 Financial Performance Benefits

The economic or financial performance of a company foresees its stronger competitive position and ensures its adaptability to changing markets and governmental factors. Previous studies have relied on economic performance measures such as sales growth, profit growth, and market share growth to represent the corporate financial performance (Flynn et al. 2010), yet others authors suggest that improving overall corporate financial performance depends on resource utilization efficiency, environmental benefits (Green et al. 2012), and cost minimization. In the manufacturing industry, financial performance benefits allow companies to adapt to changes and provide them with new product introduction capabilities (Yang et al. 2011).

Performance benefits do not only help companies improve their daily operations, but they also help them minimize cost and increase profitability (Qrunfleh and Tarafdar 2014). Chan et al. (2017) reported that supply chain agility plays an instrumental role in enhancing firm performance and that both strategic flexibility and manufacturing flexibility are essential in helping firms adapt to the rapidly changing environment of the global fashion business. Strategies such as Collaborative Planning, Forecasting, and Replenishment (CPFR) can enhance a firm's financial and operating performance in several ways. The use of information technologies in supply chains improves the coordination of interfirm activities, providing a more informed decision-making process. This results in better performance of financial indicators, such resource utilization and costs (Hill et al. 2018).

Inventory levels and policies and tools, such as just in time (JIT), have positive effects on corporate performance. They offer benefits of cost reduction throughout the production system (Elking et al. 2017). In others cases, innovation also has a considerable impact on corporate performance by improving a market position that conveys competitive advantage and superior performance. Likewise, innovations have been associated with increased firm sales. Rather than technological innovations, they seem to be the most vital factor for total sales (Lin and Chen 2007). Finally, in their work, López-Mielgo et al. (2009) reported process innovations exert a positive influence on the total quality management efforts of the organizations. Besides speed and quality aspects, innovative performance is also related to the two other elements of production performance, namely flexibility and cost efficiency.

7.4.3 Firms Benefits Associated to Non-financial Performance

Better operational performance reflects on a company's ability to satisfy customers with the right products, in the right quantity, at the right time, and in the right place. Internally, operational performance reflects on operational flexibility and waste elimination (Flynn et al. 2010; Green et al. 2012; Wong 2012; Wong et al. 2011). Quality, flexibility, and delivery reliability are the grounds for customer satisfaction, leading to long-term customer loyalty (Feng et al. 2018). A firm's operational or non-financial focus is to determine an order winner or order evaluator in terms of operational strengths (e.g., cost, quality, delivery, and flexibility). Hence, it is important to systematically build effective supply chains for manufacturers with various order winners (Chase and Jacobs 2010).

To Rai et al. (2006) competitive performance includes:

- Product delivery cycle time
- Timeliness of after sales service
- Productivity improvements (e.g., assets, operating costs, labor costs)
- Strong and continuous bond with customers
- Precise knowledge of customer buying patterns
- Increasing sales of existing products
- Finding new revenue streams (e.g., new products, new markets).

Interfirm coordination enables knowledge transfer for collaborative product design and development among supply chain members. As a result, it improves supply chain operational and financial performance (Gu et al. 2017). By increasing the level of trust and commitment in a supply chain relationship, both firms can benefit through increased levels of information sharing, leading to superior operational performance (Elking et al. 2017). Tomic et al. (2016) claim that organizations can improve business performance levels by selecting appropriate quality improvement programs depending on existing organizational culture dimensions and may thereby develop an organizational culture that enables successful quality improvements in a supply chain context.

On the other hand, it has been found that innovation strategy is an important major driver of firm performance and should be developed and executed as an integral part of the business strategy. Managers should recognize and manage innovations in order to boost corporate operational performance (Gunday et al. 2011). Finally, human resources and information technology should provide support for lean initiatives. Lean manufacturing has a significant relationship with operational performance; visual performance measures are directly related to operational performance, which also is directly related to financial performance (Fullerton et al. 2014). Sharing information through information technologies increases productivity, reduces inventories, improves resource utilization, minimizes costs, and helps detect problems better and faster (Singh et al. 2018).

7.5 Conclusions

To compete, companies today have to operate in regulated, legal and physical environments. Companies can be more productive and technologically successful from the inside, but if external conditions increase costs, their competitiveness ends up being limited (Herrera et al. 2014). Changes in productivity are both the cause and the consequence of the evolution of dynamic forces operating in the economy: technological progress, accumulation of physical and human capital, and businesses and institutional arrangements, to name but a few. Therefore, companies themselves are a determining factor of competitiveness.

Manufacturing companies are basic economic agents that respond to a competitive market environment to improve their manufacturing capabilities. Therefore, policies and strategies for increasing competitiveness must be prioritized. The only meaningful concept of competitiveness is not that of productivity. The external elements that compose the system along with it indicators can provide a more comprehensive definition (Garduño et al. 2013). Corporate competitiveness in enterprises is achieved through adequate supply chain management. In the manufacturing industry, this implies identifying the vast array of indicators that adversely affect its profitability. At a much larger scale, the competitiveness of a country depends on the microeconomic efficiency of its enterprises, government policies, and foreign investment, which all generate jobs and contribute to economic growth. It is bold, but at the same time ambitious, to believe that Mexico can improve its national competitiveness levels. As Sobrino (2005) claim, this can be achieved through local competitiveness and by attracting more foreign investment to develop new projects.

In conclusion, competitiveness in manufacturing companies has become central to the academic and industrial theme when searching, for so long, for a perfect recipe for economic profitability. Competitiveness allows companies to reaffirm their position in such a globally aggressive market environment, driven by forces of uncertainty and uncontrollable dynamics. To tell the truth, these actors are not the only reason of this work, but also those governments and legal institutions in which all the economies are founded. Mexican manufacturing companies seek to conduct effective long-term economic development projects and systematically improve their advantages by reinventing their ability to successfully penetrate complex value chain networks around the world.

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Chapter 8
Supply Chain Evaluation and Methodologies

8.1 Analysis of Performance Factors

The performance factors studied in this research (i.e., risk factors, regional factors, manufacturing practices) are analyzed from a multivariate perspective to identify their impact on supply chain performance benefits. Before introducing the concept of multivariate analysis, below we present a series of supply chain analysis methodologies reported in Avelar-Sosa et al. (2014), who performed a literature review of around 100 research articles on this matter. According to the authors, common methods and techniques for supply chain study include reverse logistics (RL), analytic hierarchy process (AHP), discriminant analysis (DiA), linear regression (LR), descriptive analysis (DA), case studies (CS), simulations (Si), exploratory analysis (EA), factor analysis (FA), and structural equations (SE), among others. As regards supply chain analysis trends, they include supply chain quality, flexibility, risk, and agility, information, and communication technologies (ICTs), enterprise resource planning (ERP), coordination and trust among supply chain partners, and performance. Table 8.1 summarizes this information.

As Table 8.1 suggests, the wide range of available methods and techniques opens the door to new horizons in supply chain analysis. Even though Avelar-Sosa et al. (2014) do not discuss this in detail, most supply chain evaluation methods and techniques study performance elements and indicators, such as delivery times, costs, customer service, competitiveness, and integration. Similarly, many of the reviewed works rely on multivariate methods, such as LR, FA, SE, and AHP, for evaluating supply chain performance indicators. For instance, even though SE were originally a research tool for the social sciences, their use has exponentially increased in other disciplines, such as industrial engineering, to quantify an issue or research aspect.

Several studies employ multivariate techniques to explore supply chain performance factors. For instance, Ranganathan et al. (2011) explored the role of information and communication technologies and networks on supply chain

L. Avelar-Sosa et al., *Evaluation of Supply Chain Performance*,
Management and Industrial Engineering,
https://doi.org/10.1007/978-3-319-93876-9_8

Table 8.1 Trends in supply chain analysis and methodologies

Areas	AHP	RL	FA	DiA	DA	Si	SCa	SE	EA	LR
ERP	0	0	0	0	0	0	1	3	0	0
Risk	1	0	0	1	2	1	1	0	0	1
Integration	0	0	0	0	1	0	3	2	0	0
Competitiveness	0	0	0	1	1	0	1	0	0	0
Quality	0	0	0	0	0	0	0	1	0	0
TIC	0	0	0	0	2	2	1	0	0	0
Performance	7	2	4	4	25	11	47	27	2	4
Collaboration	0	0	0	0	2	0	1	2	0	1
Coordination	0	0	0	0	1	2	1	0	0	0
Location	0	0	0	1	3	0	1	0	0	1
Flexibility	0	0	0	0	1	0	0	1	0	0
Agility	0	0	0	0	0	0	1	2	0	0
Trust	0	0	1	0	0	0	0	0	0	0

Source Avelar-Sosa et al. (2014)

communication, whereas Swafford et al. (2008) studied the impact of flexible processes, manufacturing, and distribution/logistics on supply chain agility. Likewise, some works have relied on multivariate analysis techniques to analyze the effects of technology on supply chain operations, ERP, and innovation channels. In fact, as shown in Table 8.2, current trends in supply chain performance analysis employ multivariate tools in the study of aspects such as ERP, ICTs, and supply chain coordination, flexibility, and location (Lu et al. 2006; Su and Yang 2010a; Zhang and Dhaliwal 2009; Ranganathan et al. 2011; Su and Yang 2010b; Ramanathan and Gunasekaran 2014; Lu et al. 2007; Kim et al. 2013; Autry et al. 2010; Akkermans et al. 2003).

All the studies discussed above have used multivariate analysis as a research tool in regional contexts. This means that they have managed to consider both internal and external operational activities, and consequently, they have assessed risk factors

Table 8.2 Multivariate methods for supply chain performance analysis

Aspect	Linear regression	Factorial analysis	Structural equations	AHP
Agility	0	0	2	0
Risk	0	0	0	1
Collaboration	1	0	2	0
Quality	0	0	1	0
Flexibility	0	0	1	0
Location	1	1	0	0
ERP	0	0	3	0
Technology adoption	0	0	1	0

and regional elements. In other words, it is possible to assess supply chain performance from a causality approach. The following sections discuss a series of causal analysis examples and define the research methodology adopted in this work.

8.2 Multivariate Analysis Methods

8.2.1 Introduction

Multivariate analysis comprises a set of statistical techniques that simultaneously measure, explain, and predict all the existing relationships between the elements of a database. These relationships can be of three types:

– Dependence relationships
– Interdependence relationships
– Classical relationships

Dependence relationships occur when one or more dependent variables are explained by a set of independent variables, whereas interdependence relationships imply mutual reliance between variables. Finally, classical relationships occur when relationships surpass the monocriteria approach. An important concept in multivariate analysis is causality, which occurs when a phenomenon determines to which extent another phenomenon occurs. Causality is a cause–consequence relationship in which one phenomenon causes, to some extent, another phenomenon (Lévy and Varela 2003).

First-generation multivariate analysis emerged in the early 1970s and initially included techniques such as principal component analysis, factor analysis, discriminant analysis, and multiple regression analysis, among others. First-generation multivariate analysis techniques used to focus on descriptive research, which relied on few statistical inferences and less a priori theoretical knowledge. Consequently, all the social sciences virtually received a dose of empiricism, even though these techniques could not analyze one construct with multiple observed variables in a single step, let alone relate these constructs (Roldán and Cepeda 2013). To address the limitations of the first multivariate analysis techniques, second-generation techniques emerged in the late 1980s. They were named structural equation models and recognized that scientific theory implies both empirical and abstract variables. The purpose of these tools is to link data with theory. Structural equation models combine two traditions, an econometric perspective that focuses on prediction, and the psychometric approach that models concepts as latent or non-observable variables, which in turn are composed of multiple observed and measured variables (i.e., indicators or manifest variables) (Roldán and Cepeda 2013; Williams et al. 2009).

Latent variables represent theoretical concepts, whereas indicators are used as inputs in a statistical analysis that provides evidence on the relationships between latent variables (Williams et al. 2009). Multivariate analyses are important because formal science researchers need to take into account multiple observed variables to understand them better. This implies acknowledging, validating, and assessing the reliability of the observed elements by means of direct measurement instruments. Structural equation models have exponentially evolved in the past 30 years thanks to the increasing use of friendly computer programs that make the estimation tasks much easier thanks to user manual and spreadsheets. Similarly, structural equation models are solid grounds to justify variance estimation in modeled cause–effect relationships.

8.2.1.1 Notion of Causality

Causality comes from the ability of the techniques to confront theoretical propositions about a cause and an effect without manipulating the variables, that is, without rigorously controlled experimental designs. Causality refers to a model's assumption, rather than to a property or consequence of the technique. Many variables tend to move along together, yet the mere statistical association between them is not enough to claim there is causality (Casas 2002). The necessary and sufficient condition of causality can be expressed as follows: Variable A is a cause of Variable B if, and only if, every time A occurs, B follows, but B never follows if A does not occur. Causal relationships occur only in the direction $A \rightarrow B$, since causality is asymmetric. However, it is impossible to distinguish between isolated regularities and a causal relationship. Thus, we can claim that a relationship between two variables is causal when we can rule out the possibility that the relationship is spurious or not causal (Lévy-Mangin and Varela 2006).

In social sciences, causal analysis refers to a set of strategies and techniques for developing causal models to explain phenomena in order to contrast them empirically. The origins of causal analysis date back to path analysis. The goal of a path analysis is to study the effects of some variables, considered as causes, over some other variables, considered as effects. Even though path analysis is widely employed in the social sciences, its popularity has lately risen in other fields and knowledge areas thanks to its versatility and ability to explain dependence and interference between multiple variables. Later in this chapter, we will discuss the concept, implications, and considerations of structural equation analyses. That said, the following section provides a brief description of some of the most common multivariate analysis methods. Even though they differ from structural equations, they possess common characteristics. Therefore, it is important to explicitly state their differences to avoid confusions.

8.2.2 Multiple Linear Regression

Regression analysis aims at estimating the average value of a dependent latent variable with respect to the values of one or more additional variables, known as explanatory variables. In this type of analyses, dependent variables are stochastic, whereas explanatory variables are generally non-stochastic. Linear regression has become increasingly popular thanks to the numerous statistical software programs that rely on it. Moreover, it is a robust process that can be adapted to an infinite number of scientific and business applications (Montgomery et al. 2006).

Multiple linear regression is a statistical technique that can be both descriptive and inferential. From a descriptive approach, multiple linear regression has the following abilities:

- Find the best linear prediction equation.
- Control some factors to evaluate the contribution of some specific variables to a linear model.
- Find structural relationships (causality studies).

The regression model can be visualized as follows:

Consider the following relationship to explain the behavior of a dependent variable (Y) with respect to n independent variables (X_1, X_2, …, X_n).

$$Y = f(X_1, X_2, \ldots, X_n) \tag{8.1}$$

where $f(X_i)$ is an implicit function form.

When this implicit function form cannot be estimated, $f(X_i)$ can be approached as follows:

$$Y = \sum_{i=1}^{n} \beta_{i+1} X_i + e \tag{8.2}$$

For $i = 1, 2, \ldots, n$, where β are function parameters, and e is the error due to the linear approximation of Eq. 8.1.

8.2.2.1 The Constant in Regression Analysis

Unlike the other coefficients in the regression equation, β does not measure changes, but rather indicates the effect measured in dependent variable Y and caused by the variables excluded from the equation and the linear approximation. In mathematical models, the constant is the ordinate intercept, or y-intercept, while in econometric models the interpretation of the constant is different. However, in some cases, as in cost functions, which include fixed costs, the regression constant can be interpreted as the intercept.

8.2.2.2 Coefficient Estimation

So far, we have discussed how coefficients can be interpreted, but we have not addressed how they are estimated. The goal of a regression analysis is to find the best estimation of the model parameters to make a close approximation to the real Y. Once all the β parameters are estimated, the residual would be the difference between the observed value of variable Y and the value predicted for variable Y based on the values estimated for the β parameters.

8.2.2.3 Statistics and Hypotheses Testing

Once the parameters are estimated, a set of statistical analyses are performed to assess the model's fit as well as the usefulness and precision of the estimations. The most common statistical tools for linear regression analyses are the following:

– Coefficient of determination

If all the observations coincided with the regression equation, a model would have the perfect fit. However, this is rarely the case. Since statistical models usually have positive and negative errors (e), it is important to have a measure of how well the observed outcomes are replicated by the model, according to the proportion of total variation of outcomes explained by the model. The coefficient of determination, denoted R^2, is a measure of goodness of fit and can be calculated as follows:

$$R^2 = \frac{\sum_{j=1}^{m} \left(\hat{Y}_j - \bar{Y}\right)^2}{\sum_{j=1}^{m} \left(Y_j - \bar{Y}\right)^2} \tag{8.3}$$

In Eq. 8.3, the numerator is the sum of squares due to regression (SSR), and the denominator stands for the total sum of squares (TSS). The coefficient of determination ranges from 0 to 1. That is from 0 to 100% of the variation in Y_j that is explained by SSR. Even though R^2 is a goodness of fit index, it should not be overused, since it can increase its value when more explained variables are added in the analysis, even though they are not significant.

– Significance of the regression coefficient

It is not enough to know how well a regression line fits the data, or to know the standard error of the estimates. It is equally important to know whether dependent variable Y is truly related to independent variable(s) X. To this end, we must perform a statistical test to determine whether the coefficients for variables X are different from 0.

8.2.3 Path Analysis

Path analysis (PA) can assess the fit of theoretical models that comprise a series of dependence relationships. Additionally, path analysis does not test causality but rather helps select or make inferences between causal hypotheses (Batista and Coenders 2000). PA can be considered as an extension of the multiple regression model. Not only does PA highlight the direct contribution from a set of independent variables, but it also emphasizes on the interaction among predictor variables and their direct influence on dependent variables. PA was originally developed in the early years of the twentieth century by Sewall Wright for phylogenetic studies. Later on, it was introduced to the social sciences thanks to the contributions of de Blalock (1964), Duncan (1966), and Boudon (1965), cited by Pérez et al. (2013). Similarly, PA became increasingly popular among psychology, sociology, economics, political sciences, and ecology studies, among others.

Unlike PA, in which each construct is represented by observed variables, structural equation models measure latent variables using multiple measures for their representation, thereby modeling the measurement error. Latent variables are theoretical constructs that cannot be directly measured, but they are associated with a set of manifest or observed variables. Although manifest variables can be directly measured, it should not be assumed that measurements are an exact reflection of the variable. In other words, random and unpredictable factors can hinder error-free measurements (Weston and Gore 2006; Pérez et al. 2013).

Researchers employing PA perform a series of regressions to analyze relationships between independent and dependent variables; that said, some variables can be both dependent and independent, depending on the relationship that is implied. Similarly, it is important to evaluate the goodness of fit of the model, that is, the extent to which the model represents the relationships between the studied variables. Path coefficients explain the impact of one variable over another variable by decomposing this impact in three blocks or paths: path from the independent variable to the intermediate variable, path from the intermediate variable to the dependent variable, and the rest of the path leading to the final variable. By using path coefficients, it is possible to know the correlations between variables after analyzing the set of effects: direct, indirect, or spurious.

As depicted in Fig. 8.1, PA is represented by diagrams that illustrate hypothetical models. In this sense, it is important to consider the following guidelines to correctly develop diagrams:

- An arrow must be used to indicate the relationship between two variables. The direction of the arrow indicates the direction of the relationship.
- A bidirectional arrow must be used to represent covariance between variables.
- Arrows represent path coefficients that indicate the magnitude of the effects in the relationships between two variables.

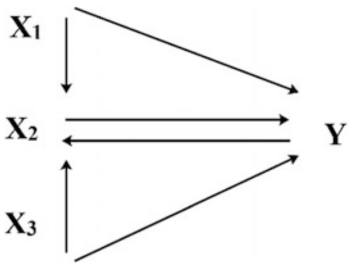

Fig. 8.1 Example of path analysis. *Source* Wright (1971)

- Those variables that receive an influence from other variables are referred to as endogenous variables. Those variables that influence other variables are known as exogenous.
- Observed variables are represented by squares, whereas latent variables are depicted using circles or ellipses.
- Direct effects occur directly from one variable to the other.
- An indirect effect between two variables occurs through one or more mediator variables.

Path models can decompose associations between latent variables through standardized coefficients, which are simply direct effects. On the other hand, indirect effects are estimated by multiplying the path coefficients found between two interrelated variables along the causal line. The statistical significance of any of the given effects can be calculated by dividing the non-standardized coefficients by the standard error. The result is a z value that allows determining the significance of the studied variables (Weston and Gore 2006). Most of the statistics used in PA assume that a multivariate distribution is normal. In this case, a violation to the assumption would be a problem, since it could affect the accuracy of the statistical test, suggesting incorrectly that there is a good fit. Therefore, it is important to conduct some tests before estimating the parameters. Some of these tests include measuring the data at the ordinal or nominal level, measuring collinearity, and using 10–20 cases per parameter and at least 200 observations (Kline 2005).

Structural equation analysis is similar to path analysis since it provides direct and indirect estimations for the observed variables. This property is illustrated in Fig. 8.1. Similarly, there is a wide range of computer programs currently available to support statistical analyses. The study of causal relationships emerged from a technique called multivariable analysis, initially proposed to work with experimental data. Structural equation analysis is a practical and versatile tool; it can effectively and efficiently adapt to all types of research and extract important and detailed information. In conclusion, PA models can have a large explanatory power. Even though they are highly similar to regression, they assume that there exist linear relationships between two observed variables, which implies that one variable has an effect over another (Casas 2002).

8.2.4 Factor Analysis

Factor analysis is a technique for generating structures of theoretical models and hypotheses that can be tested empirically, without previous model specifications or without considering either the number of factors or their relationship (Lévy-Mangin and Varela 2006). Factor analysis, as depicted in Fig. 8.2, is a way to take a mass of data and shrink it into a smaller and more meaningful data set that is also more manageable. A factor is a set of observed variables that have similar response patterns. The number of factors extracted by means of factor analysis is lower than the number of analyzed variables. Once the average values and the standard deviation values are calculated for each construct, it is important to analyze the component matrix to determine whether the items truly belong to the construct wherein they are.

Extracted factors are enough to summarize most of the information contained in original variables. Factor analysis shows which variables are explained by other variables. For instance, in Fig. 8.2, factor 1 (F_1) is explained by variables V_1 and V_2. Moreover, F_1 is related to factors F_2, F_3, and F_4. Similarly, variables V_1 and V_2 have their own measurement errors: e_1 and e_2, respectively. Factor analysis models that describe the correlations from a set of observed variables V_1, V_2 … V_n in terms of a reduced number of common factors, known as latent variables, are represented as a linear equations system as follows (García Ochoa et al. 2017):

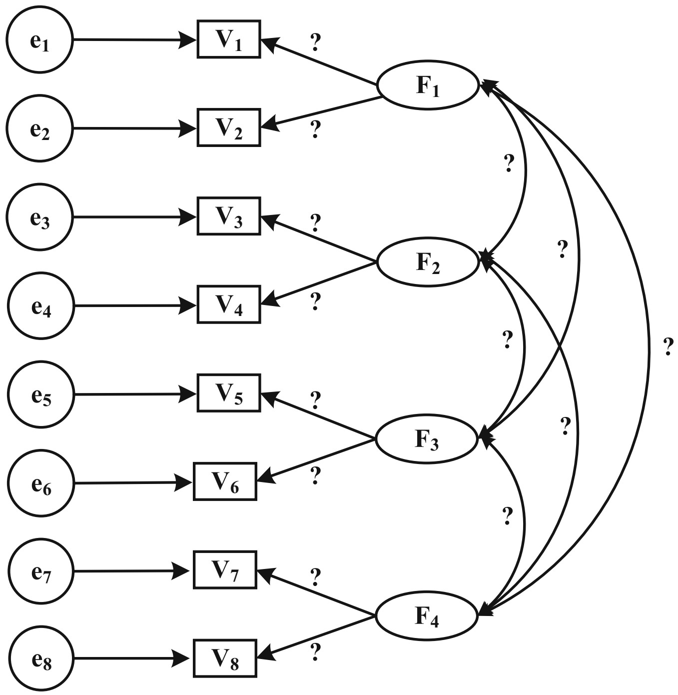

Fig. 8.2 Example of factor analysis. *Source* Prepared by the authors

$$
\begin{aligned}
V_1 - \mu_1 &= \lambda_{11} f_1 + \lambda_{12} f_2 + \cdots + \lambda_{1k} f_k + e_1 \\
V_2 - \mu_2 &= \lambda_{21} f_1 + \lambda_{22} f_2 + \cdots + \lambda_{2k} f_k + e_2 \\
&\vdots \\
V_i - \mu_i &= \lambda_{i1} f_1 + \lambda_{i2} f_2 + \cdots + \lambda_{ik} f_k + e_i \\
&\vdots \\
V_p - \mu_p &= \lambda_{p1} f_1 + \lambda_{p2} f_2 + \cdots + \lambda_{pk} f_k + e_p
\end{aligned}
\tag{8.4}
$$

In Eq. 8.4, V_i represents the observed variables obtained from the data base, although when standardized, they would have zero mean and unit variance for all $i = 1, 2, \ldots p$. On the other hand, λ_{11}, λ_{12}, …, λ_k represent regression coefficients, usually known as weights or factor loadings; f_1, f_2, …, f_k are the latent common factors, known as latent variables or non-directly observed variables, each one of them with zero mean/unit variance. Finally, residuals e_i are unobserved disturbances from the unique or specific factors. The model only works with interval variables with the same direction (García Ochoa et al. 2017).

8.2.5 Structural Equations (SE)

To describe the relationship between a variable of interest and a predictor variable when it is believed that the latter influences on the former, researchers usually rely on a simple regression model (Silva and Schiattino 2008). However, when in this relationship more than one predictor variable affects the variable of interest, it would be more convenient to propose a multiple linear regression model. Now, let us suppose that the relationship is even more complex: the variable of interest affects variable $\boldsymbol{X}$, which in turn is influenced by many more variables. Linear regression would not be enough to study this relation, since more equations are necessary. In his work on path analysis, Wright (1932) discussed such complex relationships. Later, Jöreskog (1988) proposed the name structural equations. Structural equation analysis can explain dependence relationships between independent and dependent latent variables. Figure 8.3 shows an example of structural equation analysis, where F_1, F_2, F_3, and F_4 represent independent variables explained by observed variables V_1, V_2, V_3, V_4, etc. The question mark going from F_1 to V_1 represents the percentage that explains this independent variable.

The unknown arrows connecting F_1, F_2, … etc., to variable *Result* indicate the level of importance of the factors associated either positively or negatively to this variable and the relationship between them. When researchers deal with a series of interrelated events, structural equation modeling (SEM) is the most appropriate tool, since it can simultaneously examine dependency relationships. Two of the most important characteristics of SEM are as follows:

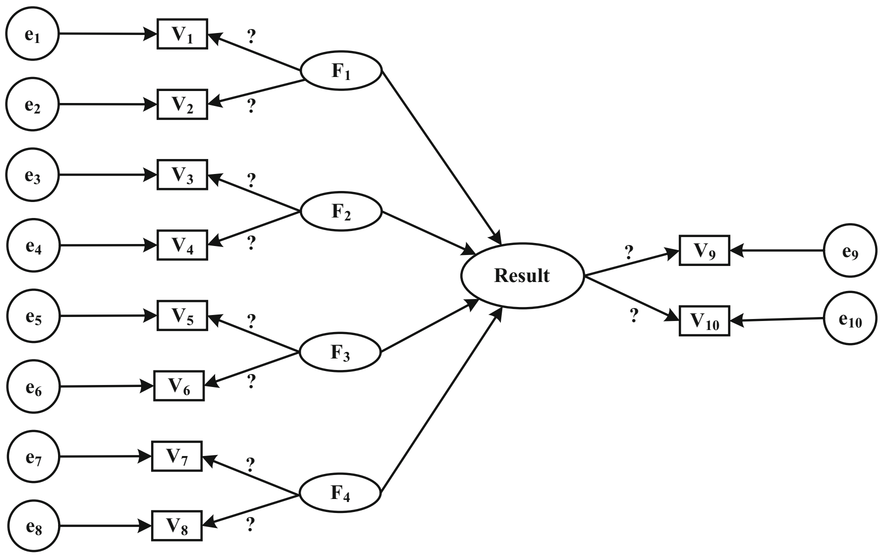

Fig. 8.3 Example of structural equations. *Source* Own

- SEM can estimate multiple relationships and interrelated dependence.
- SEM can represent both unobserved concepts in these relationships and the error measurement in the estimation process.

As depicted in Fig. 8.3, the model allows proposing causal relationships between the variables: That is, some variables cause an effect on others and can transfer these effects to other variables, thereby creating concatenations of variables (Ruiz et al. 2010). Structural equation models are a family of multivariate statistical models that can estimate effects and relationships among multiple variables. Similarly, SEM emerged from the need to rely on more flexible regression models. Structural equation models are less restricted, if compared to regression models, since they can integrate measurement errors in both criterion (dependent) variables and predictor (independent) variables. Likewise, structural equation models can be viewed as factor analysis models that allow for both direct and indirect effects between factors. Mathematically speaking, these models are more difficult to estimate if compared to other multivariate models, such as regression models or factor analysis models.

SEM became popular in 1973 thanks to the appearance of the Linear Structural Relations (LISREL) program (Jöreskog and van Thillo 1973). Later on, LISREL was improved, thereby giving birth to LISREL VI (Jöreskog and Sörbom 1986), which offered a more diverse range of estimation methods. Another method traditionally used for performing structural equation analysis was EQS (abbreviation for "equations") (Bentler 1985). Nowadays, various estimation programs, such as the Analysis of Moment Structures (AMOS) software can facilitate the task

(Arbuckle 1997). The influence of estimation programs on SEM has been so strong, that structural equation models are often referred to as LISREL models, yet international literature reports them as structural equation models or SEMs.

One of the goals of empirical research is to discover causal relationships between variables. This goal is achievable when researchers work with experimental and controllable concepts, such as physical phenomena. However, most of the variables studied in social science and behavioral studies are impossible to control, which is why researchers must rely on other alternatives. The social sciences frequently study abstract and intangible concepts known as constructs, which can only be measured indirectly with the help of indicators. In this sense, SEMs are useful tools in the study of linear causal relationships. These models do not prove causality but can support researchers in decision-making situations by rejecting those hypotheses that contradict the data or the structure of the covariance (i.e., the subjacent relationships between the variables) (Casas 2002).

Overall, a structural equation model comprises two models: the measurement model and the structural model. A measurement model represents the part that can be measured; that is, the part that describes how latent variables are measured by their corresponding manifest indicators. Measurement models inform on the validity and reliability of the observed indicators. On the other hand, a structural model describes the relationships between latent variables. The importance of a SEM-based analysis resides in the ability of the analysis to confirm a theory, or explain it to some extent, and build constructs to estimate latent variables with respect to measured variables. SEM-based models are useful tools in disciplines such as psychology, marketing, social sciences, and recently, engineering.

In the industrial engineering domain, the application of SEM is still at its early stages and thus provides great opportunities for improvement. Common SEM-based studies conducted in this area evaluate the impact of information networks on supply chain (SC) performance or assess the effects of SC risk on manufacturing and distribution processes (Swafford et al. 2006). Likewise, the literature reports SEM-based analyses of lean processes and supply logistics integration (Prajogo et al. 2016), SC collaboration (Ramanathan and Gunasekaran 2014), SC flexibility and its impact on knowledge transfer (Blome et al. 2014; Jin et al. 2014), or even the effects of SC flexibility and agility in the fashion industry (Chan et al. 2017). There are also studies aiming at analyzing the relationship between competitiveness and customer satisfaction (Subramanian et al. 2014), as well as the impact of green SC (Mangla et al. 2014), resilience (Govindan et al. 2015) and information systems (Qrunfleh and Tarafdar 2014; Tarafdar and Qrunfleh 2017).

8.3 Structural Equation Modeling (SEM)

Model design and development procedures and methodologies have greatly varied in the last twenty years. Initially, researchers used to work merely with observed variables, and all the underlying structures were clear and evident. The idea of measuring unobserved constructs emerged among the social sciences and fueled the evolution of overall measurement systems, methods, and techniques. Covariance structure models first became popular thanks to Jöreskog, Keesing, and Wiley and their works on simultaneous equations. Later on, from 1967 to 1978, these models were increasingly popularized thanks to the LISREL software and related programs.

Covariance structure models are within interdependence models for a confirmatory factor analysis of any order or degree and for dependency models in the case of a causal analysis. Scales can be either measurable or non-measurable (categorical scales vs. ordinal scales), and they indicate the level of dependence at various levels. The use of causal models has exponentially increased over time, since they allow researchers to analyze complex construct networks, wherein each network is measured by multiple variables (Lévy-Mangin and Varela 2006). In this sense, causal models can be considered as superior if compared to traditional statistical techniques, since they can incorporate abstract and unobservable constructs (Fornell 1982, 1983).

SEM is a second-generation statistical analysis technique employed to develop or test research theories. SEM includes a family of multivariate statistical tools to estimate effects and relationships among multiple variables. SEM's major advantage is that it proposes the type and direction of the hypothetical relationships between variables. Then, it estimates the parameters (Ruiz et al. 2010). Finally, note that structural equations are not only used for covariance structures, but also for variance structures in which a given percentage of variance can be explained through explanatory constructs and variables. Therefore, it is important to mention that modeling is possible thanks to the application of Partial Least Squares (PLS), which estimate the parameters. This type of modeling is known as PLS-SEM.

8.3.1 Partial Least Squares (PLS)

PLS-based SEM allows researchers to perform multiple regressions between latent variables (Batista and Coenders 2000). The goal is to depict in a model how some variables affect other variables, considering they are interrelated (Valencia et al. 2017). PLS is a multivariate analysis technique for testing structural equation models. It allows researchers to develop a comprehensive model in order to estimate path models that involve latent constructs indirectly measured by multiple indicators. Similarly, PLS can reflect the theoretical–empirical conditions where some theoretical situations are scarce or changing (Wold 1985).

The goal of PLS-based modeling is to predict which latent and observed variables are dependent. This can be achieved by maximizing the explained variance (R^2) contained in dependent variables. Definitely, PLS is designed to explain the variance of dependent latent variables, that is, to analyze the importance of the relationships and the resulting R^2 coefficient. Likewise, if compared with covariance-based methods, the PLS-based technique is rather confirmatory, not exploratory. Rather than estimating the variance of all the variables, PLS analyzes the data and relies on a sequence of Ordinary Least Squares (OLS) iterations and multiple regressions performed for each construct.

As a SEM technique, PLS sees each construct as a theoretical construct represented by its own indictors. However, the relationships between constructs must be defined with respect to previously established knowledge (theory) about the research phenomenon (Loehlin 1998). PLS relies on an iterative algorithm in which parameters are calculated by a series of least squares regression. The term partial refers to the fact that the iterative procedure involves separating the parameters instead of estimating them simultaneously (Batista and Coenders 2000). Furthermore, PLS can deal with complex models that contain a large number of constructs and interrelationships. It offers less strict suppositions on data distribution and can work with nominal, ordinal, or even interval data.

Researchers have demonstrated that PLS-based mathematical methods are fairly rigorous and robust (Romero et al. 2006). That said, the mathematical model is flexible in the sense that it does not establish premises related to measurement levels, data distribution, or sample sizes. The main goal is to perform a predictive causal analysis on complex problems that are backed up by little theory or research. It is a correlation-based technique designed to extract the main components from an *X* matrix of predictor variables and those from the related *Y* matrix to better predict the variables of the *Y* matrix. The main components of the *X* matrix are selected in a way they can completely predict the variables of the *Y* matrix. Therefore, the components of both matrices are intimately interrelated.

In conclusion, PLS can be a powerful tool thanks to its flexibility: It demands the least number of requirements in terms of measurement scales, sample size, and residual distributions. In large-sample models, the findings from both approaches (PLS-based and covariance-based) are different (Loehlin 1998). Sample size has an impact on the robustness of the statistics. As Gefen et al. (2000) suggest, even in PLS, the sample size should be a large multiple of the number of constructs in the model, since PLS is based on linear regression. Experts recommend using at least ten times more data points than the number of items in the most complex construct in the model (Barclay et al. 1995).

PLS algorithms were originally developed by Wold (1985) to address problems in the estimation procedures when multicollinearity and overparameterization occur (Chin 1998). Likewise, PLS can model both formative and reflective constructs. The former are those indicators that form or determine a construct, whereas the latter are a reflection of the underlying variation in the construct (Diamantopoulos 2008; Bollen 1989). As a result of its ability to model latent constructs under non-normality conditions and with small-sized and medium-sized samples (Chin et al. 2003), the PLS optimization technique has recently become an exclusive object of study.

8.3.2 Characteristics of PLS Path Modeling

PLS path modeling has the following four characteristics: (1) normality in data distribution is not assumed, since it is a nonparametric method that can work with relatively non-normal data; (2) few variables can be used for each construct; (3) the model can include a large number of indicator variables (more than 50 attributes); and (4) it is assumed that all the measured variance is used to explain or predict the proposed causal relationships (Hair et al. 2012, 2013). PLS-SEM methods are nonparametric optimization techniques that do not need the usual requirements of normal data to apply the maximum likelihood estimation (MLE) method. PLS-SEM methods represent analytic techniques associated with regression, since they combine a prediction-oriented econometric perspective with a psychometric viewpoint. This characteristic allows developing models with latent variables and their corresponding indicators. Similarly, it allows for greater flexibility when modeling a theory (Roldán and Cepeda 2013). Table 8.3 introduced below reports the foremost advantages of PLS path modeling.

PLS suits better predictive applications and theory development. It can be employed to suggest possible relationships and propositions that can be eventually proved, or even to confirm research theories (Chin 2010). Furthermore, PLS path modeling does not impose any assumption whatsoever regarding a specific distribution of data, and it avoids two serious problems: inappropriate solutions and factors indeterminacy. Finally, PLS path modeling sets minimum requirements as regards measurement scales (ordinal or nominal); that is, it does not demand scale uniformity (Sosik et al. 2009).

PLS modeling is robust against three inadequacies (a) skewed instead of symmetric distributions for manifest variables, (b) multicollinearity within blocks of manifest variables and between latent variables, and (c) misspecification of the structural model with small samples (Reinartz et al. 2009; Ringle et al. 2009a; Chin 2010). This method might be more appropriate when the objective is application or prediction, when the research phenomenon is relatively new or changing, when the

Table 8.3 Characteristics of PLS path modeling

Criterion	PLS characteristic
Approach	Variance-based
Objective	Prediction-oriented
Assumptions	Nonparametric (predictor specification)
Hypothesis	Optimal prediction precision
Latent variable scores	Explicitly estimated
Parameter estimates	Consistent as indicators and sample size increase
Minimal sample size	30–100 cases
Epistemic relationship	Can be modeled in either formative or reflective mode
Implications	Optimal for prediction accuracy

research work is interactive, or when the model is complex and has multiple indicators or latent variables, regardless of the level of solidness of the theoretical context (Chin 2010).

PLS path modeling can explain causal relationships between multiple variables, each one of them measured through one or more indicators. Unobservable variables hold a given relationship with observed variables. Such relationship can be viewed as a reflection effect. Each indicator can be defined as a linear function of the latent variable plus an error term. The correlation among indicators increases internal consistency. This is usually confirmed by the dimensionality, reliability, and validity tests performed on the model. Similarly, another way to view variables is as a relationship of a formative effect, in which latent variables are not always represented in the traditional fashion. They are rather composed by causal indicators, which are the linear combination of those indicators plus a disturbance.

8.3.3 Observed Variables and Latent Variables

One of the most relevant concepts in SEM is that of latent variable. Latent variables cannot be directly observed or measured with a generally accepted instrument (Schumacker and Lomax 2004). Similarly, latent variables are composed of manifest variables, also known as observed variables or indicators. In PLS path modeling, a latent variable is obtained through a linear combination of its observed variables (indicators) (Loehlin and Beaujean 2016). It is generally assumed that no measurement is perfect (Bollen 1989). As reported by Haenlein and Kaplan (2004), every real-world observation comes with a measurement error, which can comprise two parts: a random error and a systematic error. Random errors are statistical fluctuations mainly caused by the order of the survey items or by biased responses. On the other hand, systematic errors are due to the method's variance. In this sense, the value of an item is always the sum of three parts: the real value, the random error value, and the systematic error value.

When relying on PLS path modeling, three steps must be followed: Determine the nature of the relationship between indicators and constructs, assess indicator reliability and validity, and interpret structural coefficients and thus determine the model's adequacy. Additionally, PLS path models are analyzed and interpreted in two stages (Roldán and Cepeda 2013):

– Stage 1: Assess model reliability and validity. The goal at this stage is to determine whether the theoretical concepts under study are being appropriately measured through the observed variables. Reflective constructs are used to measure validity (i.e., the used measurement exactly measures what it is supposed to measure) and reliability (i.e., consistency of the results), whereas formative constructs are used to measure multicollinearity in indicators and the weights of manifest variables.

– Stage 2: Assess the structural model. The goal at this stage is to assess the magnitude and significance of the model relationships. This stage considers aspects such as explained variance, standardized regression coefficients, as well as their respective significance levels, to name but a few.

These two stages are performed to guarantee construct validity and reliability before the researcher can draw conclusions from the model (Barclay et al. 1995). These two stages are thoroughly discussed in the following chapter.

8.3.4 Sample Size in PLS Path Modeling

The PLS method usually guarantees high statistical prediction accuracy, even with small-sample models (e.g., 35–50 cases). However, when large samples are involved (i.e., more than 200 cases), estimation precision accuracy usually increases (Hair et al. 2009). Moreover, covariance-based and variance-based PLS methods usually differ in accuracy with large-sized samples.

8.3.5 Specifications of PLS Path Modeling

SEM is a unique, systematic, and integrative analysis technique because it can evaluate both measurement models and structural models. Measurement models show how each latent variable is represented by indicator variables, whereas structural models describe hypothesized causal relationships that occur among a set of dependent and independent constructs. Measurement and structural models can be mathematically represented by using simultaneous equations. Since structural equation models are developed according to available literature, hypothesized causal relationships can be visually represented. Structural equation models can model the degree to which observed variables do not perfectly describe a construct of interest.

Similarly, they can incorporate unobservable constructs measured through indicators (i.e., items, attributes, observed variables) and model the relationships among multiple predictor variables (i.e., independent or exogenous variables) and result variables (i.e., dependent or endogenous variables). Finally, structural equation models can combine and compare a priori knowledge and hypotheses with empirical data. To represent measurement and structural models, there must be enough indicators of each latent variable. A rule of thumb is that there need to be at least two indicators per latent variable in order to avoid problems when calculating degrees of freedom. That said, the ideal number of indicators is five or six (Hair et al. 2009). Figure 8.4 illustrates an example of both a measurement model and a structural model.

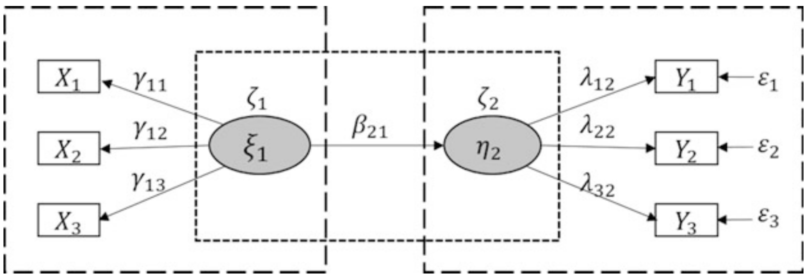

Fig. 8.4 A measurement model and a structural model in SEM. *Source* Own

8.3.6 Basic Terminology

This section discusses basic SEM terminology for both measurement models and structural models. The figures introduced below support the presented terminology. Each one of these figures is a part of Fig. 8.4, which was presented in the previous section.

To begin with, it is important to bear in mind that those variables that cannot be directly measured, but are rather represented by one or more observed variables, are known as constructs. Graphically, constructs are represented by circles or ellipses. There are two types of constructs: exogenous (ξ) and endogenous (η). Exogenous constructs act as predictor or causal variables, whereas endogenous constructs receive the causality of exogenous constructs. Indicators (or manifest variables) are observed variables representing attributes or items obtained from questionnaires or surveys. Graphically, observed variables are represented by squares (Roldán and Cepeda 2013).

Figure 8.5 illustrates a set of unidirectional relationships between variables. These relationships are depicted by arrows and represent those causal relationships than can occur internally (i.e., between constructs) and externally (i.e., between each latent variable and its indicators). Reflective indicators are unobservable constructs that reflect preexisting theoretical constructs. On the other hand, formative constructs cause or give rise to latent theoretical constructs.

Figure 8.6 depicts a series of parameters to be estimated. The direction of the arrows indicates the direction of the causality. As the figure illustrates, causality goes from construct (η) to its indicators (Y_i), and these indicators must be highly correlated. In other words, they must have high internal consistency levels (as defined by Cronbach's alpha, the composite reliability index, and the average variance extracted) to be able to explain that construct. The error is associated with the individual measures of each indicator.

The reflective measure for the *i*th indicator is (Y_i); (η) represents the construct, and (λ_i) is the factor loading of construct η over Y_i. Similarly, ε_i is the specific measurement error of Y_i, and n stands for the number of reflective indicators used to value the construct. This is denoted in Eq. 8.5.

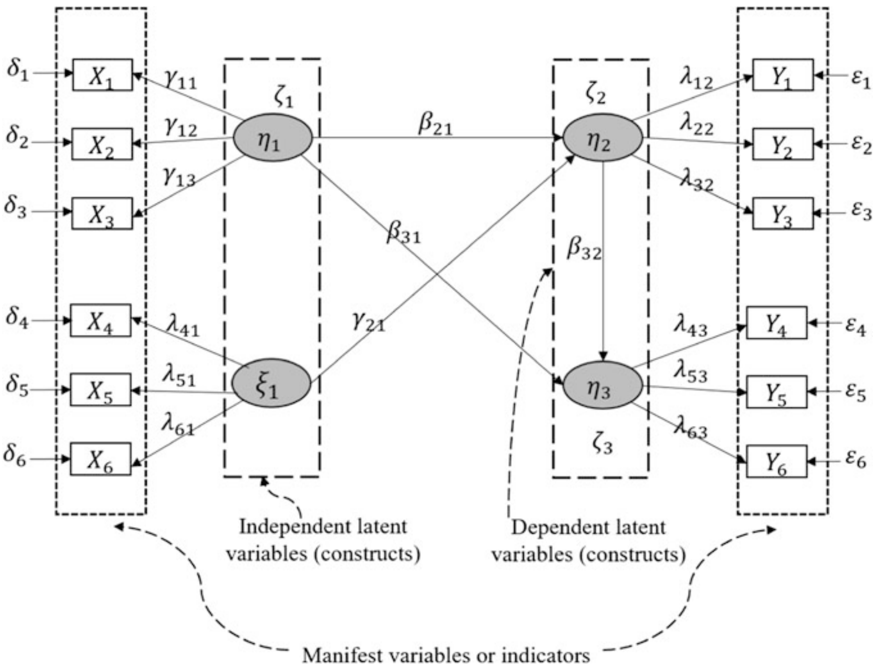

Fig. 8.5 Structural equation model with indicators, example. *Source* Own

$$Y_i = \lambda_i \eta + \varepsilon_i, i = 1, \ldots, n \tag{8.5}$$

Figure 8.6 also depicts the regression coefficients between endogenous latent variables β_{ij} and exogenous latent variable γ_{ji}, as well as the equation errors in structural model ζ_1. Causality arrows emerge from exogenous latent variables and are directed toward endogenous latent variables. Measurement errors for exogenous latent variables are noted as δ_i.

8.3.6.1 Estimations in PLS Path Modeling

Making estimations in the structural model implies estimating all the parameters. In covariance-based SEM, parameters are usually estimated using the maximum likelihood estimation (MLE) method. The goal of MLE is to find the parameter values that maximize the likelihood function, given the observations (Lomax and Schumacker 2012). Ordinary Least Squares are another common estimation method. OLS is a PLS-based and iteration-based method that can estimate unknown parameters through simple and multiple regressions (Chin and Newsted 1999). Thanks to a bootstrapping or resampling procedure, the OLS method diminishes convergence effects and finds, after a few iterations, an optimal solution.

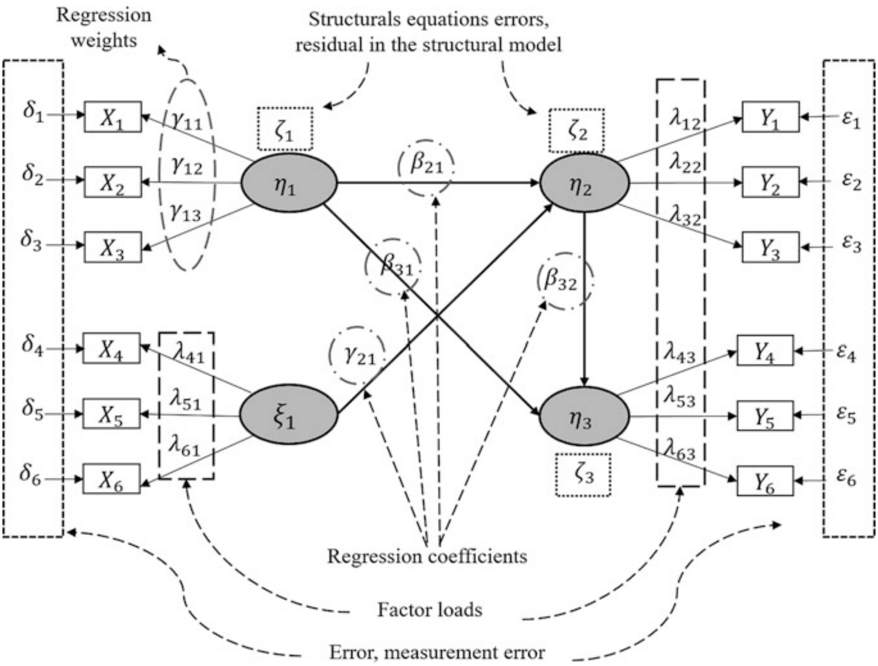

Fig. 8.6 Parameters to be estimated in a structural equation model. *Source* Own

Considering Fig. 8.7 as the reference, the estimation process can be explained as follows:

- The first iteration shows an initial value for η by simply adding values $Y_1 \ldots, Y_j$ (i.e., factor loadings $\lambda_1 \ldots, \lambda_j$ are set to 1).
- To estimate weights $\gamma_1 \ldots, \gamma_i$ in the regression analysis, η is the dependent variable and $X_1, \ldots X_i$ are the independent variables.
- These estimations are used as weightings in a linear combination of $X_1, \ldots X_i$, thereby giving a value for ξ.

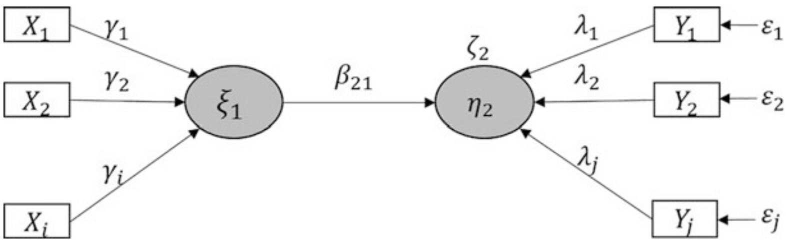

Fig. 8.7 Parameter estimation process diagram. *Source* Own

– Factor loadings $\lambda_1 \ldots, \lambda_j$ are estimated through simple regressions of $\gamma_1 \ldots, \gamma_i$ over ξ. The previous loadings are transformed into weightings to establish a linear combination of $\gamma_1 \ldots, \gamma_i$ as the new estimation for η.
– The procedure is repeated until the difference between the subsequent iterations is small.
– Finally, the simple regression coefficient β is calculated as the difference between the punctuations of both latent variables: ξ and η.
– This segmentation process for the estimation of parameters is useful for complex models and small samples.

8.3.7 *Evaluation Criteria for the Measurement Model*

The measurement model is employed to assess the reliability of the items contained in a construct or latent variable. The most common latent variable coefficients are those of internal reliability, composite reliability, convergent validity, and discriminant validity. However, it is also imperative to consider aspects such as multicollinearity, which is usually measured by the Variance Inflation Factors (VIF) index. The following paragraphs thoroughly discuss each one of these latent variable coefficients.

8.3.7.1 Reliability and Internal Consistency

Item reliability is measured using the loadings associated to a construct, which must be higher than 0.70. This implies that the variance shared between the construct and its indicators is higher than the error variance. Loadings of values 0.50 and 0.60 can be accepted at early stages of scale development (Chin 1998). Internal consistency is a measure of how well a series of items explain a construct, whereas composite reliability involves the standardized loading for each item and the measurement error. Equation 8.6 introduces the reliability estimation formula.

$$\rho_n = \frac{\left(\sum \lambda_i\right)^2}{\left(\sum \lambda_i\right)^2 + \sum \varepsilon_i} \tag{8.6}$$

where ρ_n stands for construct reliability; λ_i represents the standardized loadings of each observed variable; and ε_i indicates the variance error for each observed variable (Fornell and Larcker 1981).

8.3.7.2 Convergent Validity

Convergent validity implies that a given number of items represent the unidimensionality of a construct (Ringle et al. 2009b). Unidimensionality is measured through the average variance extracted index (AVE), which measures the overall amount of variance in the indicators accounted for by the latent construct. A rule of thumb is to set 0.5 as the minimum acceptable value, which implies that over 50% of the variance of a construct is due to its indicators.

8.3.7.3 Discriminant Validity

Discriminant validity measures to what extent a construct shares more variance with its indicators than with other model constructs. Discriminant validity can be confirmed by demonstrating that the correlations between the constructs are lower than the square root of the AVE. Another way to confirm discriminant validity is to analyze the correlations between the scores of a targeted construct and the scores of the items from the other non-targeted constructs (i.e., cross-loadings). Cross-loadings indicate how strongly a construct item loads on the other non-targeted factors. Constructs must load stronger on their corresponding items than on any other item from any other model construct.

8.3.7.4 Multicollinearity

Multicollinearity refers to a high degree of correlation (linear dependency) among several independent variables or indicators. Collinearity in constructs is usually measured with the VIF index, setting 3.3 as the maximum value (Hair et al. 2012). Finally, to assess measurement models, statistical significance is considered by using a two-tailed Student's t-distribution. A level of significance equal to or higher than 0.5 indicates that a targeted indicator is relevant to a construct.

8.3.7.5 Evaluation Criteria for the Structural Model

To evaluate the fit of a structural model, the research hypotheses must be validated through a significance test performed on each of the estimated coefficients. The one-tailed t-test is performed in situations where researchers predict a relationship or difference in a specific direction (i.e., positive or negative relationships) (Hair et al. 1999); however, when researchers can predict a relationship or difference but do not know in what direction, a two-tailed t-test is performed. A model's fit is measured according to the level of prediction for the independent latent variables, as indicated by R-Squared (R^2). R^2 values indicate the overall amount of variance in dependent latent variables that can be explained by the model. Every path or relationship between constructs should have an R^2 value higher than 0.3. Moreover, predictive variance for each dependent construct, as indicated by Q^2, must be higher than 0. All the latent variable coefficients (for measurement models) and model fit and quality indices (for structural models) are thoroughly discussed in the following chapter, which addresses the methodology of this work.

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Part III
Impact of Competitiveness on the Supply Chain Performance

Chapter 9
Methodology

9.1 Stage 1. Survey Validation

The relationships between supply chain performance and critical success factors have been explored in many industrial sectors, but not in the export-oriented manufacturing industry of Mexico. Therefore, most of what is known about the variables discussed in this book corresponds to other research contexts. The first step in this research was thus to conduct a literature review of case studies and research works conducted on supply chain evaluation whose contributions and information could be adapted to our research context. The whole reviewing process is the rational validation of the latent variables, whose validity is tested in the export-oriented manufacturing industry of Mexico. In other words, the presence of each questionnaire item in each latent variable is justified by the discussion of that item in the reviewed literature as a critical success factor or benefit (Avelar-Sosa et al. 2014; Reinheimer 2007).

9.2 Stage 2. Survey Development

To obtain the information from the manufacturing companies and validate the causal models and their corresponding hypotheses, a questionnaire was designed and developed specifically for the Mexican manufacturing industry. The goal of the questionnaire was to assess risk perception levels, regional impact factors, use of manufacturing practices, and performance benefits in the Mexican manufacturing industry. The literature review was conducted on several databases to refine the research. An example of the explored topics is the relationship between risks associated with manufacturing practices and supply chain performance (Crofton et al. 2005). Finally, the resulting questionnaire has five sections.

L. Avelar-Sosa et al., *Evaluation of Supply Chain Performance*,
Management and Industrial Engineering,
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- Demographic data
- Risk assessment
- Regional elements assessment
- Manufacturing practices assessment
- Supply chain performance

The following paragraphs thoroughly address each questionnaire section.

9.2.1 Section 1. Demographic Data

This section states the goal of the survey, details its structure, and provides the directions for the participants to answer it. Because all the responses are confidential, the first section of the questionnaire was optional; every participant could choose to either respond to it or not. The goal of the demographic section was to describe both the research population and the sample. The information assessed included:

- Current job position
- Years of experience in current job position
- Type of company
- Number of employees

Most of these variables are categorical, except work experience (Larson et al. 2009). Moreover, because this is a government-funded research, personal information, such as respondent's name, company name, and email were optional, and each participant could obtain a copy of the research results if desired. Also, knowing the number of employees that work in the companies was important for determining the size of the firms. According to the criteria set by Mexico's Secretariat of Economics (SE), companies can be classified into large-, medium-, and small-sized.

9.2.2 Section 2. Risk Assessment

The second survey section assessed perceived levels of supply chain risk. As mentioned in previous chapters, risk refers to any disruption in the supply chain that is caused by failures in any activity and adversely affects a supply chain's ability to attain the desired goals or deliver products properly. This section of the survey has three subsections, and each one of them corresponds to a latent variable as follows:

- *Supply risks*: Risk at the raw material supply process. This latent variable has six observed variables.
- *Production process risk*: Risk that may occur during the transformation or manufacturing process. This latent variable has six observed variables.

- *Demand risks*: Level of uncertainty perceived in demand with respect to sales forecasts and as a result of market dynamism and unpredictability.

9.2.3 Section 3. Regional Elements Assessment

Regional aspects usually refer to infrastructure and services available for production. They also have important effects on supply chain performance and hence competitiveness. To facilitate their analysis, this book assesses regional elements through seven latent variables:

- *Regional infrastructure*: availability of airports, roads, and Internet services for real-time communication, among others, in a particular region. This latent variable has four observed variables.
- *Costs*: expenses incurred as a result of using infrastructure and services and employing workforce in the production. This latent variable has five observed variables.
- *Services*: transport, production, and communication services, including their quality, availability, and accessibility. This latent variable has two latent variables.
- *Government*: support offered by the government at its different levels—local, regional, and national—as well as the level of bureaucracy and transparency. This latent variable has five observed variables.
- *Quality of life*: indicator of prosperity and government performance. It includes healthcare services, educational services, and social development and growth. This latent variable has four observed variables.
- *Proximity market*: degree to which a company can operate in the region thanks to its proximity to suppliers, competitors, and industrial and innovative performance. This latent variable has three observed variables.
- *Workforce*: a population's educational levels, qualifications, and skills. It is evaluated through availability, qualifications, and costs. This latent variable has three observed variables.

In total, the regional aspects assessment section of the questionnaire comprises 26 observed variables, organized in seven categories or latent variables to be tested.

9.2.4 Section 4. Manufacturing Practices Assessment

This section of the survey assesses the degree of implementation of manufacturing practices in the export-oriented manufacturing industry in Mexico. The section includes four latent variables, listed as follows:

- *Total Quality Management*: The implementation of a quality management philosophy, including activities such as statistical analyses, internal and external audits, and six sigma practices. This latent variable has three observed variables.
- *Just in Time* (*JIT*): The implementation of the JIT philosophy in the production processes. JIT is one of the pillars of lean manufacturing and aims at optimizing resources in order to improve supply chain flexibility and agility. This latent variable has two observed variables.
- *Maintenance*: The system used to maintain and improve the integrity of production machinery, equipment, and systems. Maintenance systems must focus on keeping all equipment in optimal working conditions to avoid breakdowns and delays in the production. This latent variable has three observed variables.
- *Advanced manufacturing systems*: The use of technology to improve the production process and its integration elements, including design, manufacturing, information systems, and end customers. This latent variable has three observed variables.

As can be observed, to assess the use of manufacturing practices in the manufacturing industry and the impact of these practices on supply chain performance, this book explores eleven observed variables, grouped into four latent variables.

9.2.5 Section 5. Supply Chain Performance

Since the purpose of this book is to relate critical success factors to supply chain performance, it is important to define the supply chain performance indicators that will be used. Studies on supply chain performance and management certainly address a large range of varied performance indicators; that said this book relies only on eight, which are listed as follows:

- *Delivery times*: A metric used to assess a firm's ability to fulfill orders on time with respect to customer demands. This latent variable has two observed variables.
- *Quality*: The degree to which products comply with the requirements and the rejection rate. This latent variable has two observed variables.
- *Flexibility*: In this book, flexibility comprises production flexibility and functional flexibility. Production flexibility allows the production system to respond to changes and adjustments, whether predicted or unpredicted. Functional flexibility refers to the ability of employees to perform different functions and take different schedules. This latent variable has six observed variables.
- *Customer service*: A company's rate of completed deliveries with respect to its competitors. Customer service includes customer complaints, since they influence the production flow and return rates. This latent variable has three observed variables.

– *Agility*: This is usually a complex variable. This book only assesses agility in terms of how fast a company can respond to customer needs or put a product in the market. This latent variable has five observed variables.
– *Financial performance*: Perhaps the most important supply chain performance indicator. Without a desirable financial performance, companies are unable to operate or perform any of the aforementioned activities. Financial performance also includes the cash flow rate, which is usually high as a result of an increase in sales. This latent variable has three observed variables.
– *Inventory*: Inventory turnover is the ratio that shows how many times a company's inventory is sold and replaced in a given period. This latent variable has three observed variables.
– *Transportation*: Expenses incurred as a result of transporting raw materials or products from one place to another. It also refers to a firm's ability to track such raw materials and products along the supply chain using satellites or radiofrequency systems. This latent variable has three observed variables.

9.3 Stage 3. Assessment Scale

Each section of the survey includes an assessment scale to answer the questions. The first section includes demographic data, such as job position, years of work experience, and company type, among others. On the other hand, Sects. 2–5 assess the latent variables discussed in the previous stage through a series of observed variables or items. The assessment scale used in these four sections is a five-point Likert scale (Tastle and Wierman 2007; Al-Tahat and Bataineh 2012) and can be appreciated in Table 9.1. Likert scales have proven to be reliable assessing instruments in a wide range of supply chain study environments (Swafford et al. 2006; Moon et al. 2012; Jakhar 2015; Gligor et al. 2015; Alfalla-Luque et al. 2015).

Table 9.1 Assessment scale

Value	1	2	3	4	5
Descriptor	The activity is never performed	The activity is rarely performed	The activity is regularly performed	The activity is very frequently performed	The activity is always performed
	The benefit is never obtained	The benefit is rarely obtained	The benefit is regularly obtained	The benefit is very frequently obtained	The benefit is always obtained

9.4 Stage 4. Survey Validation

The survey's validity and the scale's reliability were secured via a panel of judges. As previously mentioned, the survey took international literature, contributions, and findings as theoretical grounds, yet some of this information is not necessarily applicable to Mexico's export-oriented manufacturing industry. Therefore, the field experts evaluated the adaptability of the questionnaire, as well as the suitability and relevancy of each item with respect to our research context. Similarly, especially attention was given to word choice and grammar. The expert panel comprised supply chain experts, both scholars and engineers, and the survey validation period lasted 15 days. Considering the experts' suggestions, some items were removed from the survey, since they seemed to have little relevancy, whereas some others were added to address particular cultural and regional characteristics of the Mexican manufacturing industry.

9.5 Stage 5. Pilot Survey

Once the survey was validated, we conducted a pilot survey among a few individuals of the targeted population. This process lasted approximately a month. Conducting a pilot survey before the actual survey can potentially improve the efficiency of the main survey, since pilot surveys usually help researchers detect problems in the questionnaire that might lead to unbiased answers or items that do not make sense to the participants. After the instrument was administered, we performed the following tests on the collected data:

- We estimated the mean and the standard deviation of each survey item to assess data homogeneity. A high standard deviation value might suggest that two people or more understand a same question or item differently. In such cases, the word choice must be reconsidered.
- Respondents were asked to suggest improvements for all the items that they considered necessary.
- Items with more than two improvement suggestions were reviewed by a language expert to improve their readability in such a way as to convey the correct message.

9.6 Stage 6. Final Survey

The survey was improved thanks to the expert panel, the pilot survey, and the language experts. The final version was then administered in two versions, in Spanish and in English. The English version of the survey aimed at company managers whose mother tongue is English, and the goal was to appropriately integrate these participants in the research.

9.7 Stage 7. Survey Administration

To study the population, we requested support from the maquiladora association, AMAC—Index Juárez. We explored the association's database to find and personally reach company managers and supply chain managers of the manufacturing industry in Ciudad Juárez to whom we could administer the survey. Potential participants included procurement managers, materials planners, sales planners, and supply chain assistants, from both inside and outside of the production system. All the potential participants received an email as a formal invitation to participate in the research. Then, based on each participant's availability, we scheduled meetings to administer the survey face to face. Many participants responded to the invitation quickly, but for those who did not, another invitation was sent two weeks after. Participants who did not respond two weeks after the second invitation were discarded. Then, we tried to reach another manager from the same department as an alternative.

We also implemented the snowball sampling technique by asking the participants whether they knew a colleague or an acquaintance from a similar position, so they could be recruited as part of the sample as well. It is important to mention that we decided to administer the survey as a face-to-face interview to avoid misunderstandings and provide clarifications when needed. Moreover, this technique has been applied in similar research works (Akintoye et al. 2000; Ambulkar et al. 2015; Chin et al. 2014; Jackson and Singh 2015; Ketikidis et al. 2008; Desai et al. 2015).

9.8 Stage 8. Data Capture

The survey administration lasted three months. Once all the data were collected, we captured the information on a database using statistical software SPSS 24®, which is one of the most common software programs used to solve multiple business and research problems. Also, we had an available license for its use. The rows of the database represented each one of the administered surveys or cases, whereas the columns represented the assessed observed variables or items. Similarly, the database had two sections: a demographic section, which included categorical variables, and a section with the items from the four variables (risk assessment, regional elements, manufacturing practices, performance benefits). This second section contained only ordinal data, since these items were answered with the five-point Likert scale previously presented. Finally, it is important to mention that many demographic variables were partitioning or diving variables, which allowed us to compare the collected data across industrial sectors or company sizes.

9.9 Stage 9. Data Screening

Data screening is the process of inspecting data before its analysis and use in order to detect errors and correct them. Some data screening procedures include identifying missing values and outliers, the zero variance test, the normality test, the homoscedasticity test, and the multicollinearity test. All these procedures are thoroughly explained below.

9.9.1 Missing Values

Missing values in a survey appear when the respondent does not respond to one or more questions due to stress, a lack of knowledge, fatigue, or because a question is sensitive. Missing values are important because if they are not well managed, inferences can be misleading. To detect missing values in this research, we performed a descriptive analysis of all the items in the survey to estimate their median values. SPSS® shows the number of both valid values and missing values but does not show which are valid and which one are missing. Therefore, we proceeded to identify the missing values for all the items. Eventually, we replaced the missing values with the median value that was previously calculated. We followed this procedure since the collected data is ordinal. However, if we had dealt with interval data, missing values could have been replaced with the mean. Finally, those questionnaires with more than 10% of missing values were removed from the analysis (Hair et al. 1987, 2009).

9.9.2 Extreme Values or Outliers

Outliers are observations that lie at an abnormal distance from the other values in a sample. We applied several techniques to identify extreme values or outliers. The first was to directly observe the values of each analyzed item. Because the collected data were ordinal and were obtained from a five-point Likert scale, outliers had to be valued either higher than five or lower than one. In this sense, outliers usually occur due to data capture errors (e.g., 33 instead of 3). The second method for identifying outliers was to estimate both the standard deviation and the mean value of each item. Then, we divided the mean value between the standard deviation values and obtained a standardized value for every item. Then, we made the following decisions:

– Standardized values lower than −3 or higher than 3 can be considered as outliers at a 99% of confidence level. However, some experts suggest that values lower than 4 or higher than −4 can be integrated into the analysis (Giaquinta 2009; Hair et al. 2009; Ala-Harja and Helo 2014; Rosenthal and Rosnow 1991; Wold

et al. 2001). Values that lied outside of that range were substituted by the median value of the corresponding item.
- Also, to refine the analysis, researchers usually employ graphs or box-and-whisker plots to identify outliers (Ha et al. 2015), since these plots show the second and third quartile in the boxes and the first and four quartile on the whiskers. In SPPS, outliers can also lie inside of the employed scale range. For instance, if a sample of 300 surveys shows that 299 respondents assessed an item with the value of 4, and only one survey has a value of 1 in that same item, SPSS will detect 1 as the outlier, even if the value is inside the range of possible values (Li et al. 2014; Simpson et al. 1988). The values that lied inside of the range of possible values were kept for further analysis, whereas those lying outside were replace by the mean value of the corresponding item.

Identifying outliers is important because they can adversely affect inferences, estimations, or statistical analyses that rely on measures of central tendency and data dispersion, such as lineal regression. In other words, outliers can lead to biased analyses and represent a lack of both reliability and certainty in the study (Lem et al. 2013; Hansson et al. 1993; Chang et al. 2015). Box-and-whisker plots as well as item standardization are univariate analyses, which are frequently not enough in research works that rely on multivariate analyses of data. Therefore, to detect missing values from a multivariate perspective, we used the Mahalanobis distance (general square distance), which can analyze the correlation coefficients of the items. In other words, the Mahalanobis distance examines the interdependence between items (Todeschini et al. 2013; Patil et al. 2015; Giménez et al. 2012).

9.9.3 Zero Variance

Zero variance means there is no deviation in the data and occurs when respondents assign the same value to all the survey items. Because the SPSS® database was saved with an extension to be executed on Microsoft Excel®, we estimated both the standard deviation and the mean for each survey as measures of data dispersion (Wang et al. 2015; Manenti and Buzzi-Ferraris 2009; Lourenço and Pires 2014). As a rule, if a survey or case shows the same value across all items, the standard deviation value or variance value of that case is 0. In this research, surveys with a standard deviation value equal to or lower than 0.5 were removed from the analysis.

9.9.4 Normality Test

To reach its goal (i.e., assess the impact of risks, local factors, and manufacturing practices on supply chain performance), this book relies on dependence techniques, such as lineal regression and multiple regression. One of the requirements of both techniques is data normality, since data must not be skewed, asymmetrical, or have kurtosis problems. To assess the normal distribution of the collected data, we paid close attention to those items with a distribution outside of −1 to +1, since they could suggest the presence of outliers and therefore a lack of reliability. Next, using the standardized data, a histogram was created with a normal distribution curve overlaid (Rimoldini 2014; Loperfido 2013). Similarly, in each bias indicator, we estimated confidence intervals for each item (Xiaojun and Morris 1991; Withers 1987; Godfrey and Orme 1991). Then, we calculated kurtosis in the data, seeking for a mesokurtic distribution, which is similar to a normal distribution (Kim and White 2004). A platykurtic distribution, on the other hand, seems too flat and indicates a lot of data dispersion and hence little reliability in the central tendency estimations. Finally, a leptokurtic distribution indicates little data distribution but a big agglomeration around the mean (Galvao et al. 2013; Kerman and McDonald 2013).

9.9.5 Homoscedasticity Test

Homoscedasticity is a property of data that indicates that if these data are divided into different categories, their variance remains more or less the same. In order to determine whether the data had homoscedasticity problems, we directly observed the residual plots obtained through lineal regression, always paying close attention to having homogenous patterns (Jarque and Bera 1980; Ohtani and Toyoda 1980). Since residuals can be either positive or negative, when creating the plots, we looked for values to be proportional; that is, we sought to have the same number of positive and negative values (Bera and Jarque 1981; Giles and Giles 1996). Residual plots are important because they can refine the search for outliers since the software program assigns each item a percentage of the total error. This means that items with a high error percentage generally imply outliers.

9.9.6 Multicollinearity Tests

Multicollinearity is another problem in multiple regression analyses. It refers to a situation where certain independent variables are closely correlated to one another. Multicollinearity problems usually arise during the survey development process, when two or more items are directly related or unintentionally seek to obtain the same type of information. Usually, multicollinearity is resolved at the survey development and validation stages and after conducting a pilot survey. In this case, researchers usually remove one of the confusing items. However, when multicollinearity is not detected on time, it can also be identified through a correlation matrix, where high values indicate strong dependence between the analyzed items or variables (Mason and Brown 1975; Wang et al. 1990).

In this research, we followed two steps to analyze multicollinearity problems between variables:

- We estimated the Variance Inflation Factors, setting 3.3 as the threshold. In other words, variables exceeding the threshold normally have multicollinearity problems, as they are highly associated with other variables (Jadhav et al. 2014; Katrutsa and Strijov 2017; Park 2017).
- We estimated the condition index value for each item, which implies dividing the eigenvalues of the correlation matrix between the maximum example values identified. If the condition index value is higher than 10,000, these variables have high multicollinearity levels between them (Troskie and Conradie 1986; Zimmermann 2015).

9.10 Stage 10. Descriptive Analysis

The descriptive analysis had two stages: the descriptive analysis of the sample and the descriptive analysis of the items. For the former, we built contingency tables to display the frequency distribution of the demographic data and find the relationship between the sample characteristics. The sample's descriptive analysis helps determine the validity of the other data, those related to the latent variables. On the other hand, the items' descriptive analysis shows the measures of central tendency and dispersion estimated to find possible trends. The following sections thoroughly discuss each analysis.

9.10.1 Descriptive Analysis of the Sample

This stage refers to the analysis of the demographic data collected from the survey. As previously mentioned, we built contingency tables to identify which sectors and work positions had been surveyed, as well as the respondent's length of work experience and gender. Similarly, we analyzed the size of the surveyed companies according to the number of employees, thereby following SE's criteria for the classification of small, medium-sized, and big enterprises. The descriptive analysis allowed us to identify trends in the demographic data and have a point of reference as regards the validity of the information, since the more experienced the sample, the more reliable the data.

9.10.2 Descriptive Analysis of the Items

This analysis has two stages. At the first stage, we estimated the measures of central tendency of the data, whereas at the second stage, we estimated the measures of standard deviation. Both stages are thoroughly discussed below.

9.10.2.1 Measure of Central Tendency—Median

Usually for ordinal data, the median is used as a measure of central tendency. As previously mentioned, the information on supply chain critical success factors and benefits were collected with a Likert scale, which implies that these data are ordinal. We calculated the mean value of each one of these factors or items. Median values ranged from 1 to 5, due to the five-point Likert scale used for their assessment. In this sense, high median values suggested that the surveyed critical factors are important to the manufacturing companies or the performance benefits are always obtained. On the other hand, low median values suggested that the surveyed critical factors are not important to the manufacturing companies, or the performance benefits are never obtained (Iacobucci et al. 2015). It is important to mention that we did not estimate the mean as a measure of central tendency, since the data were not listed as intervals or ratio scales (Baxter et al. 2015), which is why the missing values and outliers were replaced by median values (Tastle and Wierman 2007). Similarly, the use of the median as a measure of central tendency is widely reported in the literature (García et al. 2013b; 2014b; García-Alcaraz et al. 2015c; Midiala Oropesa et al. 2016; Oropesa-Vento et al. 2015; Avelar-Sosa et al. 2014; Tlapa et al. 2016).

9.10.2.2 Measure of Data Dispersion—Interquartile Range

To refine the descriptive analysis of the items, we performed a data dispersion analysis by calculating the interquartile range (IQR) value of each item. We employed the IQR as a measure of data dispersion because, as previously mentioned, we dealt with ordinal data; moreover, the use of this indicator is often reported in similar research works (Avelar-Sosa et al. 2015; Villanueva-Ponce et al. 2015; García-Alcaraz et al. 2015a; Alcaraz et al. 2014; Withers et al. 1997). Mathematically speaking, IQR is the result of the third quartile minus the first quartile, or the 75th quartile minus the 25th quartile. The IQR appears in the box of a box-and-whisker plot. Also, it is commonly used as an estimator to substitute other measures, such as the standard deviation and the variance. Suitable interpretations for the IQR values calculated in this research can be read as follows:

– High IQR values indicated too much data dispersion and thus low consensus among survey respondents as regards the median values of the items (critical success factors and benefits).
– Low IQR values indicated high consensus among survey respondents as regards the median values of the items.

9.11 Stage 11. Data Validation

As mentioned in previous sections, the questionnaire was validated and improved thanks to an expert panel, a pilot survey, and a linguistics expert. Then, the data collected with this survey were screened to identify and correct errors prior to any analysis. Also, as discussed earlier in this chapter, the survey items correspond to observed variables categorized in different groups, also known as latent variables. These latent variables cover aspects of supply chain risk, regional impact factors, manufacturing practices, and supply chain performance benefits. To assess the impact of supply chain risk on supply chain performance, we found three latent variables: supply risk, demand risk, and production risk. On the other hand, regional impact factors were categorized into seven latent variables: regional infrastructure, costs, services, government, quality of life, operations, and workforce. Likewise, manufacturing practices were categorized in four latent variables: total quality management (TQM), just-in-time (JIT) system, maintenance, and advanced manufacturing systems. Finally, supply chain performance benefits were grouped into eight latent variables: delivery times, quality, flexibility, customer service, agility, financial benefits, inventories, and transport. The following sections thoroughly discuss the latent variable coefficients used to measure the validity of all these latent variables.

9.11.1 Cronbach's Alpha—Internal Consistency

The Cronbach's alpha (α) is very frequently used to measure the internal consistency of a latent variable. It can be estimated based on either the variance or the correlation indices between the observed variables (Cronbach 1951). To obtain a reliable Cronbach's alpha value, every latent variable must have at least two observed variables; otherwise, the software program cannot estimate a real value (Adamson and Prion 2013). The simple way for estimating the Cronbach's alpha is to take into account the correlation index. A rule of thumb for interpreting the Cronbach's alpha for Likert scale questions is as follows (Rindskopf 2015):

$\alpha > 0.9$ excellent
$\alpha > 0.8$ good
$\alpha > 0.7$ acceptable

$\alpha > 0.6$ questionable
$\alpha > 0.5$ poor
$\alpha < 0.5$ inacceptable

As can be observed, the higher the alpha coefficient, the higher the internal reliability of a latent variable. In this research, 0.7 is set as a reasonable threshold, yet some authors suggest much more strict values, such as 0.90 or 0.95. A Cronbach's alpha value of 0.7 can be improved by removing some items from the involved latent variable. In other words, the internal consistency of a latent variable can be improved by removing those observed variables that lie at an abnormal distance from the group, since they might be related to another latent variable (Fornell and Larcker 1981). Also, the Cronbach alpha coefficient of a latent variable is obtained via a series of iterations (Kopalle and Lehmann 1997; Nunnally and Bernstein 1994).

The Cronbach's alpha was proposed more than 50 years ago, and since then, many authors have proposed more robust versions of it (Christmann and Van Aelst 2006). In this research, we used statistical software SPSS 24® to estimate the Cronbach's alpha, setting 0.7 as the minimum acceptable value. That said, until now, there is not a unified acceptable value for this index (Kottner and Streiner 2010), especially because the rigorousness of the threshold varies across disciplines and research fields. For instance, exploratory studies might rely on α values equal to or higher than 0.6, whereas confirmatory studies usually set α values equal to or higher than 0.7 (Pinto et al. 2014).

9.11.2 Average Variance Extracted (AVE), Convergent and Discriminant Validity

It is important to look at the amount of extracted variance in each one of the factors, since the goal is to reduce the number of variables without loosing variability. Average variance extracted (AVE) is the average amount of variance in indicator variables that a construct can explain. A common rule of thumb is to set 0.5 as the minimum acceptable value for AVE (Kock 2013). AVE measures the convergent validity of the observed variables that form a latent variable. Similarly, people relate AVE with the concept of discriminant validity. In this sense, the rule is that variables should relate more strongly to their own factor than to another factor. To meet this requirement, each construct's average variance extracted (AVE) must be compared with its squared correlations with other constructs in the model. AVE values lower than 0.5 indicate that some of the variables analyzed in a given latent variable actually pertain to another construct. To avoid AVE problems, it is very important to take a look at the factor loadings of each observed variable to make sure these loadings are the highest in the latent variable where they belong. Similar to the Cronbach's alpha, satisfactory AVE values are usually obtained through an iteration process.

9.11.3 Correlation Coefficient, Predictive Validity

In order to better understand the notion of predictive validity, it is important to understand that the goal of this research is to propose causal models to associate supply chain critical success factors with supply chain performance benefits or indicators. In this sense, this research seeks to find which critical success factors best predict supply chain benefits. The proposed causal models are regression models and use the R-Squared (R^2) coefficient for measuring the amount of variance of dependent latent variables that is explained by independent variables (Lecchi 2011). The three predictive validity indices are listed below:

- R-Squared (R^2): Takes values that range from 0 to 1, and values close to the unit are always desired. The R^2 is a measure of parametric validity and is only associated with dependent latent variables (Gonzalez et al. 2013). Some authors accept values higher than 0.02, which implies that independent latent variables explain at least 2% of the variability of dependent latent variables. On the other hand, values lower than 0.02 suggest that the model has little predictive validity and low explanatory power (Kock 2013).
- Adjusted R^2: This index is similar to the R^2 coefficient, yet its estimation takes into account the size of the sample. Some authors claim that when the difference between a simple R^2 value and its corresponding adjusted R^2 value is greater than 5%, the sample's size is not appropriate (Frémont et al. 2012). The adjusted R^2 is another measure of predictive validity at the latent variable level (Wooldridge 1991).
- Q-Squared (Q^2): This is a measure of nonparametric predictive validity, and it is widely employed when the analyzed variables do not meet the normality conditions, which is a frequent phenomenon in causal model analysis (Aboalkhair et al. 2013). Q^2 values must always be higher than 0 and similar to their corresponding R^2 values, as this indicates that the data are likely to have a normal distribution. This increases the levels of reliability of the estimators.

9.11.4 Dillon–Goldstein's Rho Indicator, Composite Validity

Dillon–Goldstein's rho is considered to be a better indicator than the Cronbach's alpha. It is also used to measure internal reliability in the constructs, and it is often referred to as the standardized Cronbach's alpha. Suitable Dillon–Goldstein's rho values must be higher than 0.7 (Tenenhaus et al. 2005).

9.12 Stage 12: Hypotheses and Structural Equation Models

Once the information is validated from a statistical point of view, the next step is to develop the structural equation models to relate the research variables. Figure 9.1 presents an example of a causal model with two latent variables, which in turn are composed of two or more observed variables. In this case, the research hypothesis arises from the independent latent variable, named *Var Ind*, to the dependent latent variable, seen as *Var Dep*. In other words, the independent latent variable explains the dependent latent variable.

A structural equation model is a combination of at least two statistical techniques, such as factor analysis and regression analysis, both used in this research. The models proposed in the following chapters explain how a given independent latent variable explains a given dependent latent variable. In other words, the models explain how a series of observed variables grouped into a given dependent latent variable explain a series of other observed variables grouped into a dependent latent variable. In this sense, structural equation models are considered to be third-generation statistical techniques (Temme et al. 2006).

Structural equation models are usually more complex than Fig. 9.1, since they integrate more than two latent variables and thus more than one hypothesis. That said model hypotheses must have scientific foundations. Figure 9.2 presents a structural equation model with four latent variables. Some of them can be either dependent or independent, depending on the other latent variables involved in the relationship. This is another advantage of structural equation models. They allow researchers to comprehensively study the relationships between latent variables.

For instance, in Fig. 9.2, latent variable Var 2 depends on latent variable Var 1, and this relationship refers to the first hypothesis (H_1). However, in its relationship with Var 3, Var 2 is independent, as it explains Var 3. This relationship describes hypothesis number 3 (H_3). Similarly, the model shows that Var 1 has a direct effect on Var 2, but also on Var 3. In this sense, the relationship between Var 1 and Var 3 refers to the second research hypothesis (H_2). However, Var 1 can also have an indirect effect on Var 3 through Var 2. In this sense, we can conclude that structural equation models depict the different types of effects between latent variables. The following sections thoroughly explain these effects with respect to both Figs. 9.1 and 9.2. Similarly, H_2 will be discussed in detail below.

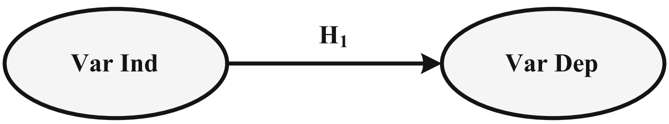

Fig. 9.1 Causal model with a simple hypotheses

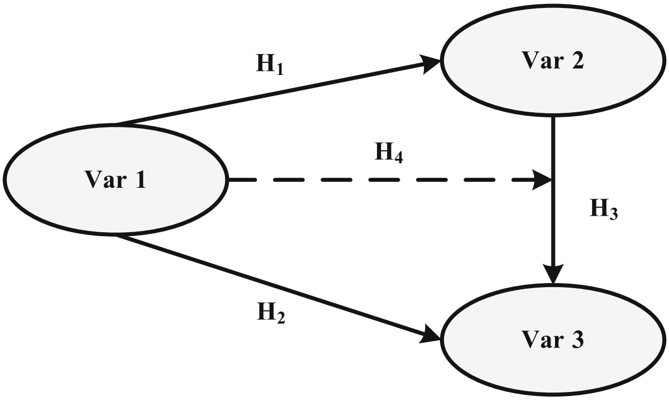

Fig. 9.2 Causal model with multiple hypotheses

9.12.1 Latent Variable Effects

Since structural equation models integrate several latent variables, the effects between them can also be varied. There are usually four types of latent variable effects in structural equation modeling:

- Direct effects
- Indirect effects and sum of indirect effects
- Total effects
- Moderating effects

9.12.1.1 Direct Effects—Hypotheses

In Figs. 9.1 and 9.2, the relationships between the latent variables are depicted with arrows. The latent variable of origin is called independent or exogenous variable, and the target latent variable is known as dependent or endogenous variable (Wold et al. 2001). The model presented in Fig. 9.2 shows three direct effects between latent variables, which correspond to hypotheses H_1, H_2, and H_3, respectively. A suitable interpretation of these hypotheses can be as follows: Latent variable x has a direct effect on latent variable y. For instance, in H_1, Var 1 has a direct effect on Var 2. To determine the direction of the arrow or effect, it is important to take into account the following aspects:

- Temporality of events: Latent variables should move from left to right for an appropriate sequence of events (Chatelin et al. 2002). For instance, when examining the causes of a student's grade, one of the impact factors might be exam preparation time. In this sense, the hypothesis would read as follows: Exam preparation time has a positive direct impact on a student's grade.

– Theoretical foundations: Not all the latent variables in a model are interrelated. Latent variables should be related based on scientific foundations found during the literature review.

Fortunately, structural equation modeling (SEM) provides indices for determining the direction of the relationships or hypotheses. For every relationship between two latent variables, SEM provides a beta (β) value as a measure of dependence, that is how much a dependent latent variable depends on an independent latent variable. All (β) values are appropriately standardized, which is why they are interpreted as standard deviations. For instance, let us suppose that the relationship between Var 1 and Var 2, that is H_1, shows $\beta = 0.54$. Then, we can claim that when latent variable Var 1 increases by one standard deviation, latent variable Var 2 increases by 0.54 standard deviations (Wetzels et al. 2009). As in traditional regression techniques, β values in SEM can be either positive or negative. When the β value is negative, the relationship between two latent variables can be as follows: Let us suppose that the relationship between Var 1 and Var 2, that is H_1, shows $\beta = -0.54$. Therefore, we can argue that when latent variable Var 1 increases by one standard deviation, latent variable Var 2 decreases by 0.54 standard deviations.

Finally, β values are also associated with a P value to determine the confidence level of the relationships. In this research, all the relationships are tested at a 95% confidence level, which means that the P value of a relationship must not be higher than 0.05. In statistics, confidence levels indicate the statistical significance of a relationship (Wold et al. 2001). If the P value of a relationship is lower than 0.05, there is enough statistical evidence to accept the hypothesis. On the other hand, if a P value is higher than 0.05, there is not enough statistical evidence to accept a relationship, which is then removed from the analysis.

9.12.1.2 Indirect Effects

As Fig. 9.2 depicts, Var 1 can have an effect on Var 3 through Var 2. This effect is given by two paths or segments: The first segment goes from Var 1 to Var 2, and the second segment goes from Var 2 to Var 3. This is a clear example of an indirect effect; however, indirect effects might also comprise more than two paths or segments (Willaby et al. 2015). Usually, in path analysis, researchers add the values of all the segments involved in an indirect relationship; this is known as the sum of indirect effects. For instance, the indirect relationship between Var 1 and Var 3 can be understood by following the segment connecting Var 1 to Var 2 (hypothesis 1) and the segment connecting Var 2 to Var 3 (hypothesis 3) (Intakhan 2014).

Indirect effects also have one β value for each segment involved in the effect and one for the sum of all these segments. As in the previous section, β represents a measure of dependence expressed in standard deviations (Kaynak et al. 2015). Similarly, a P value is associated with each β value to indicate the statistical significance of both the segments and the indirect effect. For an indirect effect to be statistically significant, it must be lower than 0.05 (Preacher and Hayes 2004).

9.12.1.3 Sum of Total Effects

Total effects in a relationship are the sum of both the direct and indirect effects. As previously mentioned, direct effects are depicted as arrows directly connecting two latent variables, whereas indirect effects occur through two or more paths or segments and involve mediating variables. As Fig. 9.2 indicates, Var 1 has a direct effect on Var 3, which corresponds to H_2; however, Var 1 also has an indirect effect on Var 3 through Var 2, which is the mediating variable. The sum of these two effects, direct and indirect, is called total effects (Intakhan 2014). Total effects also have a β value as a measure of dependence and a P value as an indicator of statistical significance. In this research, total effects are tested at a 95% confidence level, which is why they must be lower than 0.05. Analyzing total effects is very important, because direct effects sometimes might not be significant, whereas indirect effects can be significant. In such cases, the total effects are very likely to be statistically significant as well.

9.12.1.4 Moderating Effects

Figure 9.2 depicts a dotted arrow that originates in Var 1 but does not touch any latent variable but rather a relationship, namely the relationship between Var 2 and Var 3. This is an example of a moderating effect, in which Var 1 acts as a moderator variable. Moderator variables determine under what conditions an independent variable influences a dependent variable, and thus, they have an effect on this relationship. In the case of Fig. 9.2, the moderating effect can be interpreted as follows: When latent variable Var 1 increases by one standard deviation, the relationship between latent variables Var 2 and Var 3 increases β standard deviations. As in previous cases, moderating effects have a β value as a measure of dependence and a P value as an indicator of the statistical significance of the effect. Usually, moderator variables are triggers or catalyzers in the relationships between other latent variables. They can reduce or enhance the direction of the relationship, or they may even change the direction of the relationship from positive to negative or vice versa. In other words, moderator variables can be beneficial or detrimental. Their study is popular in medical sciences (Cho et al. 2004).

9.12.1.5 Effect Sizes

In structural equation models, all dependent latent variables are associated with an R^2 value as a measure of explained variance. R^2 values range from 0 to 1, and those closer to 1 indicate greater predictive validity. Figure 9.2 shows that latent variable Var 3 is explained by latent variables Var 1 and Var 2, since both have a direct effect on it (Wold et al. 2001; Kock 2013). In this sense, the R^2 value of Var 3 is the sum of the variance explained by Var 1 and Var 2. However, in order to know how much Var 1 and Var 2 individually explain Var 3, the R^2 value must be decomposed. Each one of the two portions that explain the whole variability of Var 3 is known as effect size (Chatelin et al. 2002; Tenenhaus et al. 2005).

To better understand the notion of effect size, let us suppose that Var 3 shows $R^2 = 0.65$ This indicates that, together, Var 1 and Var 2 explain Var 3 in 65%. When this R^2 value is decomposed, we might find, for example, that the explanatory power or effect size of Var 1 is 0.35 units, whereas the explanatory power or effect size of Var 2 is 0.30 units. Therefore, 0.35 + 0.30 = 0.65, which explains why Var 3 shows $R^2 = 0.65$. Since this is a hypothetical example, the effect sizes of Var 1 and Var 2 can take other values that together sum 0.65, such as 0.50 and 0.15, for example. Finally, analyzing effects sizes is very important because it allows researchers to identify which independent latent variable is more important for attaining the goals of the dependent latent variables. In this sense, the larger the effect size, the more important the independent latent variable (Rouquette et al. 2015; Boon Sin et al. 2015; Ay et al. 2015).

9.12.2 Software

Nowadays, there are several software products for variance-based and factor-based structural equation modeling, yet we decided to employ WarpPLS 5.0® for the following reasons:

– We have a license for 25 users that is valid for a year.
– As previously reported in our past research works (Alcaraz et al. 2014; García et al. 2013a, 2014a, b; García-Alcaraz et al. 2015b, c), we have experience in the use and management of this software.
– WarpPLS 5.0 uses the partial least squares that allow estimating complex cause–effect relationship models with latent variables (Kock 2015).
– The software is ideal when the study comprises ordinal data, as in this research.
– It is an ideal tool when the data do not meet normality requirements.

9.12.3 Model Fit and Quality Indices

Model fit and quality indices assess the reliability of the model, once the latent variables have been tested and validated. A structural equation model must be assessed as a whole through these indices prior to any interpretation of the findings. In this research, we employed WarpPLS 5.0 to assess the model, and we estimated the model fit and quality indices proposed by this software product. Such indices are listed below (Kock and Lynn 2012; Kock 2013):

– Average Path Coefficient (APC)
– Average *R*-Squared (ARS)

– Average Adjusted *R*-Squared (AARS)
– Average block Variance Inflation Factor (AVIF)
– Average Full collinearity VIF (AFVIF)
– Tenenhaus GoF (GoF)
– Simpson's Paradox Ratio (SPR)
– *R*-Squared Contribution Ratio (RSCR)
– Statistical Suppression Ratio (SSR)
– Nonlinear Bivariate Causality Direction Ratio (NLBCDR)

The following paragraphs provide a brief explanation of each on these indices:

– Average Path Coefficient (APC): The average value of all the β values in the model. To obtain this value, we add all the β values and divide them into the number of segments or existing relationships between latent variables. APC is associated with a *P* value, which should be equal to or lower than 0.5, since statistical inferences are tested at a 95% confidence level.
– Average *R*-Squared (ARS): It can be considered as a predictive validity index. ARS also has a *P* value, which must be lower than 0.05 in order to claim that all the R^2 values in the model are statistically significant at a 95% confidence level (Valaei and Baroto 2017).
– Average Adjusted *R*-squared (AARS): It is also a predictive validity index, yet its estimation takes into account the size of the sample. Like APC and ARS, the *P* value of AARS must be lower than 0.5 in order to claim that the model has enough predictive validity (Schubring et al. 2016).
– Average block Variance Inflation Factor (AVIF): It determines collinearity between the latent variables. Variance Inflation Factors (VIFs) measure collinearity between observed variables, whereas AVIF measures collinearity between latent variables. Generally, experts suggest AVIF values equal to or lower than 3.3, but other authors also rely on less strict values, such as 5 (Kock and Lynn 2012; Kock 2011; García-Alcaraz et al. 2015a).
– Average Full collinearity VIF (AFVIF): It is similar to AVIF and values equal to or lower than 3.3 are generally desired. If a structural equation model has AVIF and AFVIF values higher than 5, it means that two or more latent variables are measuring the same factor or dimension differently.
– Tenenhaus Goodness of Fit (GoF): It is an overall measure of model fit for PLS-based SEM (Tenenhaus et al. 2005). It is similar to the coefficient of determination used in regression analysis to know how well the data fit a curve. The Tenenhaus GoF has had several modifications, yet the conclusions remain the same (Wetzels et al. 2009). Ideal values for this index should be equal to or higher than 0.36 in order to claim that the model fits the data well. However, this threshold is only valid as long as the AVE values are equal to or higher than 0.05 (Cohen 1988).
– Simpson's Paradox Ratio (SPR): It is one of the most important indices in structural equation modeling. Sometimes, two latent variables that are analyzed independently can have an opposite effect when they are combined. Traditionally, this phenomenon is known as the Simpson's paradox. Structural

equation models should be free from this phenomenon (Roni et al. 2015). Experts suggest accepting SPR values equal to or higher than 0.7; otherwise, the direction of the model arrows must be reviewed, since one latent variable might be mistakenly considered as independent or vice versa (Pearl 2009; Wagner 1982).

– *R*-Squared Contribution Ratio (RSCR): This index determines whether model latent variables are free from negative R^2 contributions. RSCR problems generally go hand in hand with SPR problems. Experts recommend values higher than 0.7, yet 1 is the ideal value, and the result is explained as a percentage. For instance, a model with RSCR = 0.7 implies that at least 70% of the latent variables are free from negative R^2 contributions, whereas RSCR = 1 indicates that all the latent variables are free from negative R^2 contributions (Rasoolimanesh et al. 2015).
– Statistical Suppression Ratio (SSR): This index indicates whether the model is free from statistical suppressions, such as the SPR. A low SSR index usually implies inverse relationships between latent variables (Spirtes et al. 1993) or even causality effects, that is spurious relationships rather than formal statistical relationships (MacKinnon et al. 2000). Although the SSR is still under development, experts suggest accepting values equal to or higher than 0.7, yet 1 is the ideal value, since it would mean that 100% of the latent variables are free from statistical suppressions (Kock et al. 2009).
– Nonlinear Bivariate Causality Direction Ratio (NLBCDR): It is perhaps the easiest index to understand. It indicates the percentage of variables that have no reverse direction problems. The ideal value is 1, yet values equal to or higher than 0.7 are acceptable (Kock 2015).

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Chapter 10
Exploratory Analysis of the Data

10.1 Introduction and Generalities

This book introduces an empirical research developed under a quantitative approach. The purpose is to describe how modern supply chains are managed and how this management impacts on their performance outcomes. To this end, data were collected and analyzed thanks to a quantitative survey administered to a representative sample. The questionnaire provided the necessary statistical facts and estimations on the relationships between the interest variables, and it allowed us to make generalizations based on our findings.

The manufacturing industry was used to study the role of risk factors, manufacturing practices, and regional factors in exportation-oriented supply chains. Three reasons support our decision to study this industrial sector: (1) the regional workforce, (2) its contribution to the country's gross domestic product (GDP), and (3) the need to contribute to the current body of academic and industrial knowledge on supply chain management and provide improvement aspects that imply greater economic development.

After the data collection period, 225 questions were collected, thereby representing 65% of the total cases that were administered among multiple manufacturing industries. Due to confidentiality reasons, the names of the companies are omitted, yet it is possible to confirm that at approximately 81 manufacturers were surveyed. The remaining information was anonymous, since respondents did not provide their name. The number of completed surveys represented 25% of the manufacturing companies that actively operate in the country, whereas the total number of collected cases (completed or not) represented 32%. The data collection process relied on simple random sampling first, thereby considering the 324 manufacturers that were active at the time of the data collection process. Then, we relied on the stratified sampling method to identify potential survey respondents. We selected those with knowledge on logistics areas and supply chain. Finally, we adopted the snowball

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sampling technique to expand the size of the sample. Finally, the study takes into account the active participation of male and female executive managers, operational managers, engineers, supervisors, and planners, among others.

10.2 Sample Description

Table 10.1 summarizes the types of manufacturing industries involved in the study. In total, 67 respondents, or 29.8% of the sample, work in the automotive sectors, 54 participants, or 24% of the sample, belong to the electronics industry, whereas 17.33% (39 participants) work in medical manufacturing companies. Similarly, 30% of the automotive manufacturers and 18% of the electronics manufacturing companies are representatives of the region. That is, their presence in this research is similar to that in region where this research was conducted. On the other hand, some less prominent companies include machinery, consumables, and plastic manufacturers.

Table 10.2 summarizes the descriptive analysis of the sample in terms of gender. The study includes 156 male respondents and 58 female participants. Likewise, 45 of the male respondents and 21 of the female respondents work in the automotive sector. As for the electronics industry, it reports 43 male respondents, whereas 19 male participants work in manufacturing companies that are not part of this study. The table also indicates little participation from the services, packaging, communications, plastic, consumable, and metal industries. Finally, 11 participants did not report their gender and/or their working sector. This information was not compulsory.

Table 10.3 summarizes the information with respect to company size, which was measured by employee number. Namely, small companies or enterprises have 11–50 workers, whereas medium-sized companies employ from 51 to 200 employees. Finally, large companies rely on more than 201 direct employees. As the table

Table 10.1 Industrial sector and participation

Industrial sector	Frequency	Percentage
Automotive	67	29.80
Electronic	54	24.00
Medical	39	17.33
Machinery	10	4.44
Consumables	8	3.55
Plastics	6	2.70
Metals	6	2.70
Packaging	3	1.33
Communications	2	0.09
Other	30	13.33
Total	225	100

Table 10.2 Industrial sector and sample gender

Industrial sector	Female	Male	Not specified	Total
Automotive	21	45	1	67
Electronic	9	43	2	54
Medical	12	24	3	39
Manufacturing services	1	9	0	10
Consumables	1	6	1	8
Plastics	1	5	0	6
Metals	3	3	0	6
Packaging	0	2	1	3
Communications	1	0	1	2
Other	9	19	2	30
Total	58	156	11	225

Table 10.3 Company size

Number of employees	Frequency	Percentage (%)	Size
Less than 50	13	5.77	Small
From 51 to 100	11	4.88	Medium
From 101 to 200	7	3.11	Medium
From 201 to 500	39	17.33	Large
More than 500	151	67.11	Large
Not stated	4	1.77	–
Total	225	100	–

indicates, 13 of the surveyed companies (5.77%) are small, 18 are medium-sized (7.99%), and 190 are large. Large companies represent 84.44% of the research sample. Similarly, notice that four participants did not report this information.

This research also takes into account job positions and work experience. This information is summarized in Table 10.4. Notice that 136 of the respondents have 4–10 years of work experience, and 46 participants have more than 10 years. Conversely, only 25 of the surveyed employees have one year of work experience. They are technicians, operators, and specialists. In this sense, the information gathered by the questionnaire can be considered as reliable. The study includes the participation of 54 managers, 50 planners, and 40 supervisors, in addition to 18 engineers in areas such as quality, production, and warehouse. Finally, 11 participants did not state their job position and/or length of work experience.

In conclusion, the data reported in this section is a valuable contribution to our understanding of supply chain performance in the export-oriented manufacturing industry in Mexico. However, the missing information could have allowed us to improve our inferences in terms of workforce and corporate experience, yet we, as researchers understand the decision of companies and employees to remain anonymous.

Table 10.4 Work experience and job positions

Industry	Years of work experience						Total
	0–1	2–3	4–5	6–10	>10	Not specified	
Automotive	0	0	1	1	1	0	3
Electronics	3	11	12	10	17	1	54
Medical	4	2	4	6	2	0	18
Machinery	4	16	5	6	8	1	40
Consumables	3	1	1	3	1	0	9
Plastics	6	3	7	2	6	0	24
Metals	1	2	2	1	0	1	7
Packaging	3	17	11	12	7	0	50
Communications	1	1	2	4	4	8	20
Total	25	53	45	45	46	11	225

10.3 Descriptive Analysis of Risk Factors

The descriptive analyses here discussed rely on measures of central tendency, position, and data deviation to indicate data concentration with respect to the scale. Similarly, we take into account the consensus among the respondents as regards the answers. However, notice that this chapter discusses only those items that passed the validity tests when their corresponding latent variable was tested. In this sense, readers might notice some degree of discrepancy between the items listed in the survey and those addressed in the descriptive analyses. The process of item removal will be thoroughly discussed in later sections, after describing the purpose of a factor analysis.

The descriptive analysis of risk factors is summarized in Table 10.5. The measured used to analyze these items are thoroughly discussed in the methodology chapter. Similarly, all the items are listed with respect to their median value (third column). To interpret the results of each measure, we discuss, as an example, item 5: *Suppliers always coordinate their processes with ours.* The mode value (i.e., 4) indicates that we obtained greater data concentration with respect to the survey scale used. In other words, most suppliers maintain good communication with manufacturers. As for the median value, it indicates the midpoint of the answers, thereby implying that more than 50% of the respondents consider supplier–manufacturer communication as important. In all the remaining items, the median value is similar, yet it is important to take into account the 25th and 75th percentiles. These indicate that more than 50% of the answers for item 5 are distributed around scale values 3 and 5. That is, only 25% of the respondents claim that their suppliers do not coordinate their processes with those of the company.

Overall, the measures reported in Table 10.5 on risk items and latent variables can be interpreted as follows:

Table 10.5 Descriptive analysis of risk attributes

Item description	Mode	Median	25th	75th	IQR	Kurtosis
Supply risks						
3. Suppliers always deliver quality materials	4	3.72	3.06	4.43	1.37	0.171
5. Suppliers always coordinate their processes with ours	*4*	*3.67*	*3.03*	*4.38*	*1.35*	*0.357*
2. Suppliers always deliver complete and exact orders	4	3.55	2.71	4.32	1.61	−0.585
4. We always maintain communication with our suppliers to reduce failures	4	3.55	2.69	4.34	1.65	−0.504
1. Suppliers always deliver orders on time	4	3.5	2.69	4.23	1.54	−0.468
Production process risk						
7. Production processes are greatly affected by a lack of logistics services (customs, transportation, safety, warehouses)	4	3.14	2.02	4.24	2.22	−1.151
9. Production processes are greatly affected by a lack of good connectivity with target markets	2	2.6	1.69	3.58	1.89	−0.89
8. Production processes are greatly affected by the poor efficiency of banking services (banks, insurances)	2	2.47	1.54	3.53	1.99	−0.825
10. Production processes are greatly affected by a lack of efficiency in telecommunication services	1	2.2	1.32	3.34	2.02	−0.801
Demand risks						
14. Demand is communicated by customers through real-time information systems	4	3.72	3	4.48	1.48	−0.207
15. Demand is visible for both the manufacturing company and its suppliers	4	3.6	2.72	4.41	1.69	−0.578
13. Demand is always communicated in advance	4	3.43	2.44	4.3	1.86	−0.972
16. Finished products are stable and do not affect production schedules	4	3.29	2.28	4.2	1.92	−0.99

- As regards supply risks, companies need raw materials to keep the production flow and meet customer needs. However, these materials must be delivered according to the specified quality standards. This item seems to be the most important as it has the highest median value. Nevertheless, the difference between the median value of this item and item 1, which holds the last place, is relatively small. In conclusion, managers prefer quality to punctual deliveries.
- As for production processes, the analysis demonstrates that the major source of risk is a lack of logistic services associated with customs, transportation, safety, and warehousing. This is an area of opportunity for local authorities, because these services are important criteria for company location. On the other hand, the item with the lowest median value refers to the poor efficiency of telecommunication systems. However, the value still indicates that such services are adequate for local manufacturing companies.
- Finally, demand as a risk factor is usually the result of demand requirement that are not properly communicated through the existent information systems. As a remainder, ICTs are the most important aspect for the production process, and here they gain importance to communicate with customers and suppliers. In other words, ICTs are not only useful inside the production process, but also outside of it. On the other hand, the item with the lowest median value concerns demand stability, which affects production planning. Such results confirm that demand uncertainty or changes are truly a risk factor.

The interquartile range (IQR) is a measure of data dispersion and indicates the absence or presence of consensus among participants. For instance, the IQR value on item 5 is 1.35 and indicates good consensus. The IQR can be interpreted according to the sense of the sentence formulated for the item (e.g., for item 5, most respondents agree that suppliers coordinate their processes with those of the company). Finally, kurtosis is another measure used to describe the distribution. In item 5, kurtosis has a value of 0.357, which indicates a good distribution of the data around the median and confirms that the item's obtained variance is enough to explain it.

10.4 Descriptive Analysis of Regional Factors

This section discusses the descriptive analysis of the regional impact factors to be explored in the models with respect to supply chain performance. Table 10.6 summarizes the results. As in previous cases, the items are listed in descending order according to their median values. Item 27 will be used as an example of interpretation as follows: The mode value (i.e., 4) indicates that the data mostly concentrate around this value, and that most of the respondents agree with the fact that quality in services and information technologies improves supply chain operations.

Table 10.6 Descriptive analysis of the regional attributes

Item description	Mode	Median	25th	75th	IQR	Kurtosis
Regional infrastructure						
19. Internet availability and quality allow me to improve my job	4	4.38	3.72	4.92	1.2	1.013
17. The availability of elements such as land, energy, and telecommunications facilitates the economic development of regional companies	4	4.2	3.48	4.8	1.32	0.104
18. If compared to other regions, the quality of telecommunication systems and transportation infrastructure here makes my job easier	4	4.17	3.47	4.75	1.28	0.994
20. The services offered in industrial parks help my job be more competitive	4	3.87	3.13	4.61	1.48	0.231
Regional costs	4	3.74	2.88	4.52	1.64	−0.332
22. Labor costs make my job be more competitive	4	4.12	3.39	4.73	1.34	0.406
21. Land costs make me more competitive	4	3.57	2.74	4.38	1.64	−0.682
23. Telecommunication (telephone, television, radio) costs do not affect my competitive strategy	4	3.42	2.51	4.23	1.72	−0.517
24. The costs of public services (water, electricity, gas) do not exceed the budget	3	3.09	2.23	3.93	1.7	−0.727
25. Costs incurred in support services (banks, external transporters) are low	3	2.98	2.2	3.82	1.62	−0.542
Services	4	3.69	2.86	4.47	1.61	−0.528
26. Available transportation systems, financial systems, and ICTs make my job easier	4	4.14	3.39	4.76	1.37	0.65
27. The quality of transportation systems, financial systems, and ICTs makes my job easier	4	3.99	3.22	4.68	1.46	0.153
Government	4	4.19	3.52	4.75	1.23	1.15
32. Federal administration efficiency and transparency make my job easier	3	3.31	2.5	4.03	1.53	−0.245
31. Protection procedures for foreign investment are appropriate	3	3.29	2.52	3.95	1.43	0.126
30. Federal support makes my job easier	3	3.17	2.38	3.86	1.48	−0.138
28. Municipal support makes my job easier	3	3.13	2.35	3.84	1.49	−0.107
29. State support makes my job easier	3	3.11	2.37	3.8	1.43	0.066
Quality of life	4	4.12	3.44	4.71	1.27	1.362
33. Overall, the quality of life in the region is favorable	4	3.34	2.41	4.12	1.71	−0.629

(continued)

Table 10.6 (continued)

Item description	Mode	Median	25th	75th	IQR	Kurtosis
36. The climate favors social growth and development	4	3.28	2.39	4.07	1.68	−0.648
34. Education quality and availability are adequate and sufficient	4	3.23	2.25	4.02	1.77	−0.827
35. The availability and quality of healthcare services are sufficient	2	2.88	1.99	3.8	1.81	−0.879
Proximity	4	4.08	3.37	4.72	1.35	0.524
39. Proximity to target markets makes me more competitive	4	4.09	3.39	4.7	1.31	1.127
38. Local competition promotes innovation in the company	4	3.66	2.96	4.42	1.46	−0.248
37. Supplier availability and proximity are good and sufficient	4	3.42	2.53	4.21	1.68	−0.851
Workforce	4	4	3.3	4.66	1.36	0.853
42. Employee experience and competence allow the company to easily reach its goals and follow its policies	4	4.05	3.29	4.68	1.39	0.678
41. The availability of engineers, managers, and operators is enough for the company to operate effectively	4	3.88	3.15	4.58	1.43	0.378
40. The level of education and skills of the people matches those required in the company	4	3.75	3.07	4.47	1.4	−0.303

On the other hand, the median value (i.e., 3.99) indicates that more than 50% of the respondents agree with the fact that quality services and information technologies are key supply chain performance factors. Finally, the 25th and 75th percentiles reveal that more than 50% of the answers to this item are distributed around values 3 and 5, and thus only 25% of the same disagrees, totally disagrees, or has a neutral perception on the role of services and information technologies. Finally, according to the IQR value (i.e., 1.46), there is good consensus among respondents as regards the median value of the item, whereas the kurtosis value (i.e., 0.153) indicates good concentration of data around the median and enough explained variance.

A brief description of each construct that belongs to this category of regional impact factors is provided below:

- As regards regional infrastructure, the most important aspect for managers in the manufacturing industry is Internet quality and availability. This claim is strongly related to what we previously discussed regarding the role of information and communication technologies. Similarly, notice some degree of disagreement with respect to the services offered in industrial parks. Apparently, they do not seem to have enough impact on operational performance.

- As for regional costs, company managers consider labor costs as the cost-related element that makes companies the most competitive. The median value of this item is 14.12; however, service costs have the lowest median value. The difference between these items is remarkably high and indicates that services offered in industrial parks are not appropriate enough. This represents an area of opportunity for the government to improve.
- Corporate managers consider that the availability of regional transportation services is adequate; however, their quality is not high enough. This is another area of opportunity for the local government. Notice that even though this construct only integrates two items, their median values are adequate.
- Government, as a construct, includes five items and reports median values lower than 4, which might reflect improvement opportunities in terms of governance. In this category, the best-ranked item is associated with federal administration efficiency and transparency; however, the worst-ranked concerns governmental support received from the state. In other words, the federal government is better ranked than the regional government.
- The quality of life construct is integrated by four items, yet none of them reaches a median value higher than 4. Such results also indicate potential improvement opportunities for the government and local social planners. Likewise, company managers consider that the overall quality of life in the region is good, yet healthcare programs can be improved.
- As for proximity aspects, the best-ranked item is associated with the proximity to target markets—in fact, this item does have a median value higher than 4. On the other hand, foreign suppliers are less positively ranked. In this sense, it is important to mention that most of the products assembled in the region are exported to the USA, yet the parts come from multiple countries around the world. The result of this construct also represents an area of opportunity from which local businessmen can take advantage and become important local suppliers.
- Finally, regional workforce is another important factor for supplier performance. The best-ranked item has a median value higher than 4 and involves the level of work experience of the employees; however, the least positively ranked item is associated with employee educations and skills, which do not seem to match the needs of the company. As a potential improvement area, governments are responsible for supporting and improving educational programs, especially at undergraduate levels, in such a way as to meet the expectations and needs of the manufacturing industry.

10.5 Descriptive Analysis of Manufacturing Practices

The attributes in Table 10.7 were used to perform the descriptive analysis of the four manufacturing practices. As in previous sections, the table shows the measures used to analyze the items: mode, median, percentiles, interquartile range, and kurtosis. Item 51 (i.e., *Our company effectively uses CAD, CAM, and CAE* programs) will be used in this section to interpret the measures found. First, since the mode value is equal to 4, we can conclude that most of the gathered data concentrate around this value. Moreover, the sample agrees with the claim that the companies where they work effectively use advanced manufacturing technology.

As regards the whole category, we can confirm that most of the gathered data concentrate around the value of 4, as indicated by the mode values. Likewise, the percentile values indicate that more than 50% of the answers are distributed around values 3 and 5, according to the survey scale. In this sense, it is concluded that the

Table 10.7 Descriptive analysis of manufacturing practices

Item description	Mode	Median	25th	75th	IQR	Kurtosis
Total quality management						
44. Our company always performs quality audits	4	4.41	3.77	4.95	1.18	0.363
43. Our company always implements statistical process control	4	4.14	3.37	4.77	1.4	1.091
45. Our company always implements the Six Sigma methodology	4	4.04	3.16	4.75	1.59	0.29
Just in time						
47. Our company always focuses on reducing inventories	4	4.21	3.47	4.81	1.34	0.475
46. Our company implements the just-in-time philosophy in all the manufacturing processes	4	3.87	3.08	4.61	1.53	0.236
Maintenance						
48. Our company implements preventive and predictive maintenance programs	4	4.3	3.56	4.88	1.32	0.58
49. Preventive and predictive maintenance programs have a good performance	4	3.99	3.2	4.68	1.48	0.341
50. Rapid process changes are effective and efficient	4	3.76	2.98	4.55	1.57	−0.327
Advanced manufacturing technology						
52. Our company is interconnected with all its partners through information systems	4	4.03	3.3	4.67	1.37	0.807
53. Our company has flexible manufacturing technology	4	3.99	3.11	4.7	1.59	−0.057
51. Our company effectively uses CAD, CAM, and CAE systems	4	3.79	3.02	4.56	1.54	0.23

manufacturing companies in the region implement good manufacturing practices and continuous improvement programs. As for the kurtosis values, item 43 reports the highest value; it is higher than 1 and falls into the limit criteria: 3.3. Overall, all the manufacturing practice attributes have values close to 4, which are appropriate. That said, the following conclusions can be proposed for the four constructs in this category:

- As regards total quality management (TQM), we found that the manufacturing practices implement quality processes and audits to monitor these processes. Such practices are supported by a better statistical process control and the Six Sigma methodology, even though the last item shows the lowest value in the construct.
- Quality can be multidimensional, and delivery times are one of such dimensions. In this sense, JIT can be directly responsible for delivery time performance. In this construct, inventory reduction is considered as the most important aspect, as it increases turnover levels and avoids storage costs. On the other hand, according to the value of the second item, JIT is not successfully implemented in all the production processes.
- Another important aspect that keeps the continuous flow of materials is machinery maintenance. The surveyed managers agree that the surveyed companies have preventive maintenance plans and programs, since this item reports the highest median value. On the other hand, the least positively rated item refers to changeover times, which implies that SMED plans might need further development and improvement. In this sense, as demand changes, SMED plans must be reviewed and adjusted when necessary, as this would allow demand risk factors to be mitigated.
- Finally, as regards advanced manufacturing technology (AMT), the most important aspect is communication between departments, supply chain partners, suppliers, and customers through information systems. Conversely, design support systems such as computer-aided design (CAD), computer-aided manufacturing (CAM), and computer-aided engineering are ranked last. This might be due to the fact that most manufacturing companies located in the north of the country are manufacturers; that is, they manufacture and assemble parts with designs that are pre-established and sent by external companies.

10.6 Descriptive Analysis of Supply Chain Performance

Supply chain management has become an important element for competitiveness. Modern companies pay closer attention to their assets and are thus open to different decision-making strategies that both directly or indirectly affect their performance and provide them feedback in terms of supply chain management. The importance of supply chain performance assessment lies in the set of indicators that can be used to evaluate effectiveness and efficiency. In this sense, it is important to take into account the following factors:

- Costs
- Agility
- Flexibility
- Services
- Commitment
- Integration
- Trust
- Resource utilization
- Sustainability

Table 10.8 lists the descriptive analysis of the attributes used to evaluate supply chain performance in the manufacturing companies. The table also includes the measures used in the analysis: mode, median, the 25th and 75th percentiles, kurtosis, and the IQR. Mode values range from 3 to 4, yet item 56 reports a model value of 5, which is the highest possible value. Such results imply that the majority of the sample considers that the surveyed manufacturing companies comply with the quality standards set by customers.

Overall, the items have high median and mode values that suggest mild and good supply chain performance. However, notice that the scale used in this part of the questionnaire is different from that used in the other sections. As for the IQR, we found values higher than 2, which indicate appropriate consensus among respondents as regards the median values of the items. As for kurtosis, eight attributes have a value higher than 1, yet all fall into the limit criteria (+3.3 *y* −3.3).

To provide an example, item 56 has a mode value of 5 that falls into the category "*very good.*" The value of the 25th percentile is 3.96, whereas the value of the 75th percentile cannot be appreciated in the table due to its high value that exceeds 3 (regular level of the scale used). Such results imply that the majority of the data concentrate around the value of 4; as a result, the median value is remarkably close to 5. Therefore, according to the description of the item, it is concluded that the quality that companies offer in their products always meets customer requirements. Finally, as observed in the table, it is always important to interpret the results with respect to the item description. This will provide us with an overview of how the surveyed manufacturing companies operate and how their supply chains are managed.

According to the analysis results, it is possible to propose the following conclusions:

- The two items comprised in the *Delivery Times* construct have a median value higher than 4 that denote their importance. The first item indicates that the manufacturing companies rely on a just-in-time production, which in turn has an impact on product delivery times (item 2).
- Another important indicator of supply chain performance is quality. In this sense, and according to the surveyed manufacturing companies, product quality

Table 10.8 Descriptive analysis of performance attributes

Item description	Mode	Median	25	75	IQR	Kurtosis
Deliver times						
54. Our products are delivered following the just-in-time philosophy	4	4.07	3.31	4.71	1.4	1.053
55. Our company always delivers complete orders	4	4.03	3.25	4.68	1.43	0.171
Quality						
56. Our product quality complies with customer requirements	5	4.5	3.96		3.96	1.107
57. Product quality is satisfactory (no complaints in the last three years)	4	3.74	2.88	4.52	1.64	−0.332
Flexibility						
58. Setup times have been improved during the last three years	4	4.08	3.35	4.71	1.36	1.278
61. It is possible to adapt the processes to demand changes	4	3.97	3.31	4.6	1.29	1.168
60. Employees have multifunctional skills	4	3.8	3.17	4.49	1.32	0.146
59. Work contracts are flexible	4	3.78	3.06	4.53	1.47	0.394
62. Inventory levels can be rapidly adjusted according to the demand	4	3.69	2.86	4.47	1.61	−0.528
63. Product changes are performed with agility	4	3.66	2.89	4.41	1.52	0.015
Customer service						
66. Our company responds to customer needs in terms of times and costs	4	4.19	3.52	4.75	1.23	1.15
64. Overall, our company has delivered complete orders during the last three years	4	4.16	3.45	4.76	1.31	1.138
65. If compared to similar companies, our company has the best rate of complete deliveries	4	3.87	3.22	4.57	1.35	0.219
Agility						
71. Our company adjusts to the delivery requirements of customers	4	4.31	3.69	4.83	1.14	0.404
69. Our company effectively responds to unexpected demand	4	4.17	3.49	4.75	1.26	0.54
67. Product development cycle times have improved in the last three years in order to reach the desired target markets	4	4.12	3.44	4.71	1.27	1.362
68. If compared to similar companies, our company has improved product development cycle times	4	4.1	3.42	4.71	1.29	0.912
70. We improved product customization rates	4	4.09	3.41	4.69	1.28	0.284

(continued)

Table 10.8 (continued)

Item description	Mode	Median	25	75	IQR	Kurtosis
Financial performance						
72. Our market strategy focuses on total costs reduction	4	4.29	3.62	4.85	1.23	0.697
74. The rate of sales growth has improved in the last years	4	4.08	3.37	4.72	1.35	0.524
73. Our cash flow has improved in the last three years	4	4.02	3.31	4.68	1.37	0.798
Inventory						
77. Our company has reduced inventory levels in the last three years	4	4.03	3.3	4.68	1.38	1.211
75. Return on inventory has improved in the last three years	4	4	3.3	4.66	1.36	0.853
76. Return on inventory in the industry has improved in the last three years	4	3.87	3.21	4.56	1.35	0.629
Transportation						
80. Transportation quality has improved in the last three years thanks to authorized retailers and outsourcing	4	3.75	3.1	4.47	1.37	0.619
79. Satellite tracking systems have improved raw material and product deliveries in the last three years	4	3.57	2.81	4.34	1.53	0.178
78. Costs of raw material and product transportation are low	3	3.19	2.41	3.89	1.48	−0.527

always meets customer requirements. This item has the highest median value in this category. On the other hand, the companies seem to have experienced customer complaints in the last months. This item shows the lowest median value.

- As for supply chain flexibility, the construct is composed of six items. The best-ranked can be associated with setup times in machines, which allows companies to make constant changes in the production lines in a versatile manner. In fact, this item is the only one to report a median value higher than 4. As a reminder, the maintenance practices studied in the manufacturing practices construct received great significance in the analysis, yet it seems that product changes are low or do not have the required agility. This might be due to the fact that any change in any product must be authorized by the matrix company abroad. As a result, changes are delayed not due to technical issues, but rather to administrative issues.
- *Customer service* is another important performance indicator. Increased agility and flexibility are expected to increase customer satisfaction. In this construct, the results indicate that the surveyed companies can successfully respond to customer needs in terms of costs and time; however, if compared to similar

companies, the surveyed enterprises do not seem to have the best rate of complete orders. This is an important improvement area.

- *Flexibility* is seen as a source of supply chain agility. In this research, this construct includes five items, all of them with median values higher than 4. According to the table, the most important item is associated with punctual delivery times promised to customers. In other words, the manufacturing companies always seek to comply with delivery requirements. On the other hand, it seems that product customization rates can be improved. Such improvements can be implemented when companies can make rapid changes in the production lines and produce smaller batches.
- *Financial Performance* is the main reason why the remaining performance benefits are sought. This construct comprises three items with median values higher than 4. The best-ranked item is associated with total cost reduction strategies, whereas the existing levels cash flow are not always what managers expect.
- *Inventory* management is another indicator of supply chain performance. In this research, it is studied through three items; two of which have median values than 4. The best-ranked item is inventory reduction, whereas return on inventory levels must be improved.
- Finally, *Transportation* is a supply chain indicator explored through three items, whose median values are lower than 4. According to the descriptive analysis results, the manufacturing companies pay close attention to the quality of the hired transportation systems (i.e., outsourcing). However, raw material and product transportation costs can be improved. This might be a challenging task, since all the raw materials used in these companies are imported from other countries.

10.7 Exploratory Factor Analysis

An exploratory factor analysis examines intercorrelations between the studied attributes and determines whether a subset of items is highly correlated with some items and little correlated with others. Items that simultaneously have high factor loadings (higher than 0.3) on multiple factors must be discarded from the analysis (Hair et al. 2013; Hair et al 1998; Hair et al. 2016). The exploratory factor analysis performed in this work relies on a principal component analysis with *Promax* rotations. In doing so, we do not discriminate between variables on whether they are independent or dependent. This is rather determined when analyzing the variance in the relationships. To reduce the items into smaller groups, known as factors, we rely on a correlation matrix, a commonality matrix, and the eigenvalue of each construct. When an eigenvalue is lower than 1, the variable cannot be explained by itself and does not contribute to the variance of the other variables; therefore, it must be discarded.

Initially, we took into account the Kaiser–Meyer–Olkin (KMO) index in each construct to assess sampling adequacy. The goal was to evaluate validity by comparing the theory with the collected data. To this end, we used the 225 collected surveys that were completely answered by the sample. We found that a factor analysis was feasible, following the rule of four times the number of items included in the analysis. An exploratory factor analysis was then performed for 51 items to be grouped into risk factors, manufacturing practices, and regional impact factors. The following sections discuss the factor loadings as well as the extraction percentage in each latent variable. Similarly, we introduce the results of the KMO test as well as Bartlett's test of sphericity (BTS) to determine the efficiency of the constructs, the degrees of freedom (df), and the *P* value from the statistical significance test.

10.7.1 Risks Factors

This section discusses three latent variables associated with supply chain risks: demand risks, supply risks, and production process risks. Table 10.9 illustrates the construction process for these latent variables. Notice that some of the items were removed since they could not be statistically associated with any latent variable. As for latent variable *Supply Risks*, six items were removed from the analysis and will not be part of the models. This latent variable is successfully validated, since the KMO value is higher than 0.8 and the *P* value is lower than 0.05. On the other hand, items 11 and 12 were removed from latent variable *Production Process Risk*. The KMO value is higher than 0.8, and the *P* value is lower than 0.05. This latent variable has enough validity. Finally, latent variable *Demand Risks* preserves its initial items, as none on them was removed. Similarly, its efficiency indices are appropriate.

10.7.2 Regional Factors

This category includes seven latent variables. Table 10.10 summarizes the indices obtained after performing the factor analysis. Some of the latent variables only include two items, and they all have barely acceptable KMO values. However, they are integrated in the structural equation models.

The items of each latent variable are listed in descending order according to their factor loadings. All the items remain in the analysis, since the factor loadings are high and the extraction levels are adequate. Furthermore, notice that the *P* value associated with the BTS is significant. Finally, the *Services* construct only comprises two items; however, according to the BST, the construct remains for further analyses.

Table 10.9 Factor analysis of risk attributes

Latent variable and parameters	Factor loading	Extraction
Supply risks		
(KMO = 0.802 BTS: CS = 503.677.147, df = 10, *P* value = 0.000)		
1. Suppliers always deliver orders on time	0.805	0.648
2. Suppliers always deliver complete and exact orders	0.818	0.669
3. Suppliers always deliver quality materials	0.793	0.628
4. We always maintain communication with our suppliers to reduce failures	0.786	0.617
5. Suppliers always coordinate their processes with ours	0.782	0.611
Production process risk		
(KMO = 0.801 BTS: CS = 381.147, df = 6, *P* value = 0.000)		
7. Production processes are greatly affected by a lack of logistics services (customs, transportation, safety, warehouses)	0.518	0.719
9. Production processes are greatly affected by a lack of good connectivity with target markets	0.776	0.881
8. Production processes are greatly affected by the poor efficiency of banking services (banks, insurances)	0.745	0.863
10. Production processes are greatly affected by a lack of efficiency in telecommunication services	0.690	0.831
Demand risks		
(KMO = 0.778 BTS: CS = 340.942, df = 6, *P* value = 0.000)		
13. Demand is always communicated in advance	0.828	0.686
14. Demand is communicated by customers through information systems in real time	0.794	0.630
15. Demand is visible for both the manufacturing company and its suppliers	0.868	0.754
16. Finished products are stable and do not affect production schedules	0.768	0.590

10.7.3 Manufacturing Practices

This category includes 11 items, distributed in four constructs or latent variables. Table 10.11 illustrates the factor analysis results. According to the results, it is possible to conclude the following:

- All the items remain in their corresponding latent variables. Since the factor loadings and extraction levels are appropriate, none of the items had to be removed.
- All the KMO values are acceptable as they are higher than 0.7.
- The *P* values associated with the sphericity test are lower than 0.05; hence, it is concluded that the correlation matrix is not equal to the identity matrix. Consequently, it is possible to proceed with further analysis with the obtained constructs.

Table 10.10 Factor analysis of regional attributes

Latent variable and parameters	Factor loading	Extraction
Regional infrastructure		
(KMO = 0.719 BTS: CS = 212.151, df = 6, P value = 0.000)		
17. The availability of elements such as land, energy, and telecommunications facilitates the economic development of regional companies	0.797	0.635
18. If compared to other regions, the quality of telecommunication systems and transportation infrastructure here makes my job easier	0.780	0.608
19. Internet availability and quality allow me to improve my job	0.760	0.578
20. The services offered in industrial parks make my job be more competitive	0.683	0.466
Regional costs		
KMO = 0.781 BTS: CS = 83.828, df = 10, P value = 0.000)		
21. Land costs make me more competitive	0.681	0.464
22. Labor costs make my job be more competitive	0.545	0.497
23. Telecommunication (telephone, television, radio) costs do not affect my competitive strategy	0.678	0.460
24. The costs of public services (water, electricity, gas) do not exceed the budget	0.816	0.666
25. Costs incurred in support services (banks, external transporters) are low	0.760	0.577
Services		
KMO = 0.5 BTS: CS = 205.941, df = 1, P value = 0.000)		
26. Available transportation systems, financial systems, and ICTs make my job easier	0.943	0.888
27. The quality of the transportation systems, financial systems, and ICTs makes my job easier	0.943	0.888
Government		
KMO = 0.808 BTS: CS = 808.461, df = 10, P value = 0.000)		
28. Municipal support makes my job easier	0.897	0.804
29. State support makes my job easier	0.917	0.841
30. Federal support makes my job easier	0.887	0.787
31. Protection procedures for foreign investment are appropriate	0.705	0.497
32. Federal administration efficiency and transparency make my job easier	0.748	0.559
Quality of life		
KMO = 0.730 BTS: CS = 359.096, df = 6, P value = 0.000)		
33. Overall, the quality of life in the region is favorable	0.770	0.593
34. Education quality and availability are adequate and sufficient	0.880	0.774
35. The availability and quality of healthcare services are sufficient	0.852	0.726
36. The climate favors social growth and development	0.733	0.538

(continued)

Table 10.10 (continued)

Latent variable and parameters	Factor loading	Extraction
Proximity		
KMO = 0.698 BTS: CS = 99.102, df = 3, *P* value = 0.000)		
37. Supplier availability and proximity are good and sufficient	0.725	0.525
38. Local competition promotes innovation in the company	0.851	0.724
39. Proximity to target markets makes me more competitive	0.710	0.504
Workforce		
KMO = 0.712 BTS: CS = 215.366, df = 3, *P* value = 0.000)		
40. Employee experience and competence allow the company to easily reach its goals and follow its policies	0.834	0.696
41. The availability of engineers, managers, and operators is enough for the company to operate effectively	0.859	0.738
42. Employee experience and competence allow the company to easily reach its goals and follow its policies	0.852	0.726

Table 10.11 Factor analysis of manufacturing practices

Latent variable and parameters	Factor loading	Extraction
Total quality management		
(KMO = 0.724 BTS: CS = 300.034, df = 3, *P* value = 0.000)		
43. Our company always implements statistical process control	0.880	0.774
44. Our company always performs quality audits	0.859	0.738
45. Our company always implements the Six Sigma methodology in processes	0.901	0.811
Just in time		
(KMO = 0.500 BTS: CS = 65.205, df = 3, *P* value = 0.000)		
46. Our company implements the just-in-time philosophy in all the manufacturing processes	0.752	0.867
47. Our company always focuses on reducing inventories	0.752	0.867
Maintenance		
(KMO = 0.770 BTS: CS = 272.937, df = 3, *P* value = 0.000)		
48. Our company implements preventive and predictive maintenance programs	0.851	0.724
49. Preventive and predictive maintenance programs have a good performance	0.915	0.836
50. Rapid process changes are effective and efficient	0.821	0.674
Advanced manufacturing technology		
(KMO = 0.792 BTS: CS = 180.379, df = 3, *P* value = 0.000)		
51. Our company effectively uses CAD, CAM, and CAE systems	0.797	0.635
52. Our company is interconnected with all its partners through information systems	0.842	0.709
53. Our company has flexible manufacturing technology	0.849	0.721

10.7.4 Supply Chain Performance

Table 10.12 summarizes the results of the factor analysis completed on the eight supply chain performance constructs. According to such results, the following interpretations can be provided:

- All the items remain in their corresponding latent variables.
- The factor loadings and extraction levels of the items are appropriate.
- The *P* values associated with the sphericity test are lower than 0.05; hence, it is concluded that the correlation matrix is not equal to the identity matrix.
- Two constructs have a KMO value equal to 0.5, yet they remain in the analysis because they only have two items each.

Table 10.12 Factor analysis of supply chain performance benefits

Latent variable and parameters	Factor loading	Extraction
Delivery times		
(KMO = 0.500 BTS: CS = 49.661, df = 1, *P* value = 0.000)		
54. Our products are delivered following the just-in-time philosophy	0.851	0.724
55. Our company always delivers complete orders	0.851	0.724
Quality		
(KMO = 0.500 BTS: CS = 46.467, df = 1, *P* value = 0.000)		
56. Our product quality complies with customer requirements	0.847	0.717
57. Product quality is satisfactory (no complaints in the last three years)	0.847	0.717
Flexibility		
(KMO = 0.807 BTS: CS = 367,704, df = 15, *P* value = 0.000)		
58. Setup times have been improved during the last three years	0.660	0.535
59. Work contracts are flexible	0.631	0.598
60. Employees have multifunctional skills	0.669	0.648
61. It is possible to adapt the production processes to demand changes	0.747	0.557
62. Inventory levels can be rapidly adjusted according to the demand	0.753	0.568
63. Product changes are performed with agility	0.752	0.565
Customer service		
(KMO = 0.792 BTS: CS = 180.379, df = 3, *P* value = 0.000)		
66. Our company responds to customer needs in terms of times and costs	0.803	0.644
65. If compared to similar companies, our company has the best rate of complete deliveries	0.805	0.648

(continued)

Table 10.12 (continued)

Latent variable and parameters	Factor loading	Extraction
64. Overall, our company has delivered complete orders during the last three years	0.843	0.710
Agility		
(KMO = 0.788 BTS: CS = 631.066, df = 10, *P* value = 0.000)		
67. Product development cycle times have improved in the last three years in order to reach the desired target markets	0.835	0.697
68. If compared to similar companies, our company has improved product development cycle times	0.844	0.712
69. Our company effectively responds to unexpected demand	0.782	0.611
70. We improved product customization rates	0.835	0.698
71. Our company adjusts to the delivery requirements of customers	0.784	0.614
Financial performance		
(KMO = 0.712 BTS: CS = 150.136, df = 3, *P* value = 0.000)		
72. Our market strategy focuses on total costs reduction	0.663	0.539
73. Our cash flow has improved in the last three years	0.842	0.710
74. The rate of sales growth has increased in the last years	0.868	0.753
Inventory		
(KMO = 0.696 BTS: CS = 398.385, df = 3, *P* value = 0.000)		
75. Return on inventory has improved in the last three years	0.930	0.865
76. Return on inventory in the industry has improved in the last three years	0.923	0.851
77. Our company has reduced inventory levels in the last three years	0.832	0.693
Transportation		
(KMO = 0.748 BTS: CS = 154.618, df = 3, *P* value = 0.000)		
78. Costs of raw material and product transportation are low	0.930	0.865
79. Satellite tracking systems have improved raw material and product deliveries in the last three years	0.923	0.851
80. Transportation quality has improved in the last three years thanks to authorized retailers and outsourcing	0.832	0.693

10.8 Conclusions

This chapter discusses two descriptive analyses and one confirmatory analysis. The first two analyze the sample and the items, whereas the last one determines which items can remain in their corresponding constructs or latent variables. According to the results, the following conclusions can be proposed:

- Three-fourths of the sample represents large manufacturing companies with solid and well-established supply chains.

- The automotive and electronics industries are the most representative in the region. They were also the most prominent in the survey.
- Only 25 survey respondents have less than two years of work experience in their current position. This demonstrates the reliability of the gathered data.
- Companies pay close attention to potential supply chain risk factors and strive to mitigate them.
- As for regional infrastructure, the surveyed companies consider that Internet services are satisfactory; however, they also claim that the healthcare services provided to them are not adequate. Along with support services costs, this item has the lowest median value.

As for supply chain performance, it is concluded that the managerial actions and plans developed and executed have allowed the Mexican manufacturing companies to comply with the necessary quality requirements demanded by customers. However, once more, costs associated with raw material and product transportation are highlighted as a potential improvement area.

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Chapter 11
Supply Chain Risks in Supply Chain Performance

11.1 Model Variables

This section discusses the latent variables used to analyze the effects of supply chain risks on supply chain performance through the models. Three latent variables are used to study supply chain risks. These variables appear in section II of the survey and can be listed as follows:

- *Supply Risks*
- *Production Process Risk*
- *Demand Risks*

On the other hand, supply chain performance benefits are studied through eight latent variables, listed as follows:

- *Delivery Times*
- *Quality*
- *Flexibility*
- *Customer Service*
- *Agility*
- *Financial Performance*
- *Inventory*
- *Transportation*

For further information on these latent variables and their corresponding observed variables (or items), please consult the methodology section, as well as the survey developed for this research (see appendix section).

L. Avelar-Sosa et al., *Evaluation of Supply Chain Performance*,
Management and Industrial Engineering,
https://doi.org/10.1007/978-3-319-93876-9_11

11.2 Simple Models: Risk—Supply Chain Performance

To provide a clearer and sounder understanding of the analyses that are conducted and discussed in this chapter, this section initially introduces two simple models, and then, some other more complex models are discussed. The simple models associate only two latent variables, whereas the complex models comprise three or more latent variables. The first simple model analyzes the relationship between *Supply Risks* and *Delivery Times*.

11.2.1 *Simple Model A:* Supply Risks—Delivery Times

This model proposes only one relationship between two latent variables: *Supply Risks* and *Delivery Times*. The former is considered as a latent variable related to supply chain risk factors, while the latter is considered to be one of the eight supply chain performance benefits. The goal of this model is to determine whether late deliveries from suppliers have a negative impact on final product delivery times. The graphic representation of the model is introduced as Fig. 11.1. As can be observed, *Supply Risk* is the independent latent variable and product *Delivery Times* is the dependent latent variable.

11.2.1.1 Hypothesis Formulation: Simple Model A

To support the model proposed in Fig. 11.1, we conducted a review of related literature. According to Delbufalo (2015), perceived risks between suppliers and manufacturers have an impact on multiple supply chain performance aspects, such as *Delivery Times*, information sharing, knowledge sharing, asset specificity, capital-skill complementarity, and supply chain governance management. Furthermore, Mumtaz et al. (2018) claim that solving environmentally-related supply risk factors can improve supply chain performance, including product *Delivery Times*.

Some research works have studied the potential effects of *Supply Risks* on supply chain performance. For instance, Chen et al. (2013) proposed the same hypothesis as this model but in another context. The authors did not find any direct effect in the relationship between *Supply Risks* and *Delivery Times* but rather indirect effects, which occurred through additional variables, including internal processes.

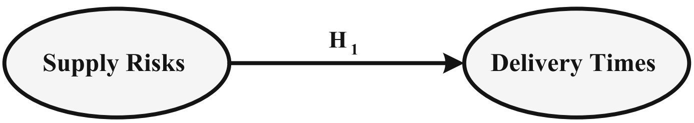

Fig. 11.1 Simple Model A proposed: *Supply Risks—Delivery Times*

The hypothesis depicted in Fig. 11.1 posits that as *Supply Risks* increase, supply chain performance, in terms of *Delivery Times*, decreases. Similar research works confirm the feasibility of this relationship (Wagner and Bode 2008; Zsidisin 2003). However, in order to test it and measure its effects—which might be positive or negative—the relationship will be statistically validated. This analysis validates the statistical significance and the direction of the relationship. In this sense, the hypothesis depicted in Fig. 11.1 (H_1) can be read as follows:

H_1. *Supply Risks* in the manufacturing industry have a negative direct effect on final product *Delivery Times*.

11.2.1.2 Validation of Simple Model A and Conclusions

Validating this hypothesis implies measuring the direct effect between these two latent variables. Notice that this model cannot report indirect effects, since these occur through additional latent variables, known as mediating variables (see Chap. 9). Therefore, the results of this validation are illustrated in Fig. 11.2, which reports three estimated parameters. That is, β indicates the magnitude of the effect, p represents the statistical significance of the relationship, and R^2 indicates the amount of variance in the dependent latent variable (i.e. *Delivery Times*) that is explained by the independent latent variable (i.e. *Supply Risks*). As a reminder, for a relationship to be statistically significant, its corresponding P value must be lower than 0.05.

The results of the validation performed on the latent variables are reported in Table 11.1. As can be observed, the two latent variables have acceptable coefficient values, which implies that the model complies with all the latent variable validation criteria discussed in the methodology chapter. For instance, we can confirm that the model has good predictive validity, since the R^2, adjusted R^2, and Q^2 values in the dependent latent variable are higher than 0.02. Furthermore, all the Cronbach's alpha and composite reliability values are higher than 0.7.

Once it is verified that the latent variable coefficients are appropriate, the model must be evaluated as a whole construct. In this sense, the estimations of the model fit and quality indices can be listed as follows:

– Average Path Coefficient (APC) = 0.451, $P < 0.001$
– Average R-Squared (R^2) (ARS) = 0.204, $P < 0.001$

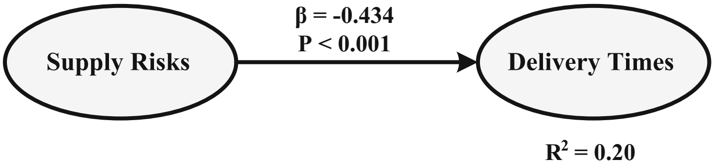

Fig. 11.2 Simple Model A evaluated: *Supply Risks—Delivery Times*

Table 11.1 Latent variable validation—simple Model A

Coefficient	*Supply Risks*	*Delivery Times*
R-Squared (R^2)		0.188
Adjusted R^2		0.185
Composite Reliability	0.897	0.84
Cronbach's Alpha Index (CAI)	0.856	0.618
Average Variance Extracted (AVE)	0.635	0.724
Full Collinearity VIF	1.627	1.736
Q-Squared (Q^2)		0.188

- Average Adjusted R-Squared (AARS) = 0.200, $P < 0.001$
- Average block VIF (AVIF) not available
- Average Full collinearity VIF (AFVIF) = 1.242, acceptable if ≤ 5, ideally ≤ 3.3
- Tenenhaus GoF (GoF) = 0.361, small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36
- Sympson's Paradox Ratio (SPR) = 1.000, acceptable if ≥ 0.7, ideally = 1
- R^2 Contribution Ratio (RSCR) = 1.000, acceptable if ≥ 0.9, ideally = 1
- Statistical Suppression Ratio (SSR) = 1.000, acceptable if ≥ 0.7
- Non-Linear Bivariate Causality Direction Ratio (NLBCDR) = 1.000, acceptable if ≥ 0.7

According to hypothesis H_1 and the model validation results, the following conclusions can be proposed:

H_1. There is enough statistical evidence to claim that *Supply Risks* in the manufacturing industry have a negative direct impact on final product *Delivery Times*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.434 standard deviations.

This hypothesis has a limited contribution if its values are only reported. In other words, researchers must interpret model hypotheses in such a way as to provide a sound understanding of the importance and implications of these relationships within the phenomena that is studied. For instance, the relevancy and implications of H_1 can be discussed as follows:

- If manufacturing companies do not receive raw materials on time and in the correct amount, they will be unable to guarantee final product delivery times to their customer. Unfortunately, problems at the supply stage of the supply chain cause an adverse chain reaction subsequent supply chain stages.
- Similarly, if manufacturing companies and suppliers do not communicate with each other clearly and on an ongoing basis, or if their processes are not synchronized, manufacturers will be unable to guarantee final product deliveries for their customers.
- Finally, if manufacturing companies and suppliers do not rely on real-time communication management technologies, such as MRP, MRP II, and SAP, it might be difficult to solve supply problems on time. Consequently, final product deliveries will be compromised.

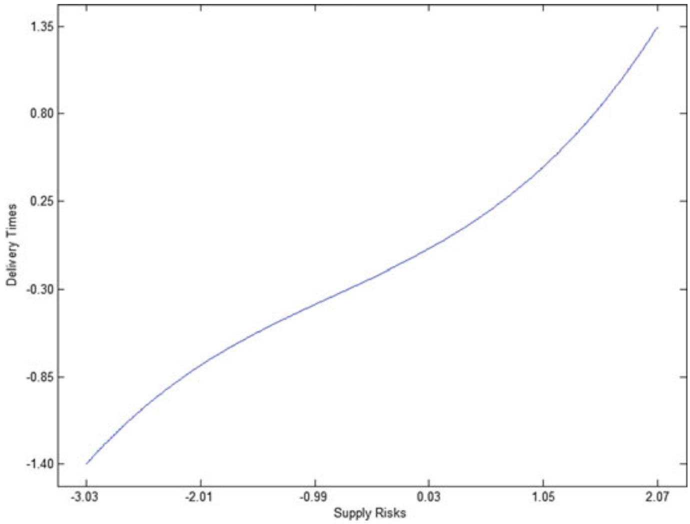

Fig. 11.3 Relationship between *Supply Risks* and *Delivery Times*

These interactions between *Supply Risks* and *Delivery Times* can be more easily understood and analyzed when building a graph of the standardized values of the two latent variables. Since latent variable *Delivery Times* acts as the dependent latent variable, it is placed on the axis of ordinates. On the other hand, *Supply Risks* is placed on the axis of abscissa, as it is the independent latent variable. Figure 11.3 depicts the behavior between the latent variables and indicates that as supply problems increase, final product *Delivery Times* are more frequently affected. The importance of this relationship lies in the fact that *Delivery Times* are an indicator of both supply chain performance benefits and operational performance (Neeraj and Neha 2015; Shepherd and Günter 2011).

11.2.2 *Simple Model B:* Production Process Risk—Inventory

This model integrates two latent variables: *Production Process Risk*, as the independent latent variable, and *Inventory*, as the dependent latent variable. As previously mentioned, *Inventory* benefits are an indicator of good supply chain performance. The goal of this model is to test whether *Production Process* problems can affect *Inventory* management capabilities in manufacturing companies. Figure 11.4 depicts the model.

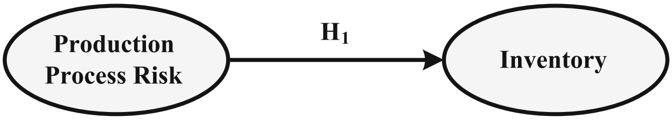

Fig. 11.4 Simple Model B proposed: *Production Process Risk—Inventory*

11.2.2.1 Hypothesis Formulation: Simple Model B

Production Process Risk imply variations in the whole manufacturing system. There are two main risks sources in production processes: (1) human resources along with the machines that they operate, (2) and the flow of raw material inputs and the degree of operability between workstations. Unfortunately, production risks can compromise inventory availability and thus timely deliveries. As a consequently, supply chain performance is affected.

Some authors have discussed the impact of *Production Processes Risk* on *Inventory* performance and have sought to determine the effects of poor inventory management on corporate performance. For instance, Zhao and Cao (2015) claim that because *Production Process Risk* and product develop development aspects can adversely affect supplier-buyer relationships, companies must implement strategies to mitigate the negative effects of production process problems on final product delivery times and commitment to customers. Similarly, Srai et al. (2015) highlight some of the major challenges for current manufacturing companies, which include ensuring continuous improvement of production processes and implementing robust industrial transformation strategies focused on improving delivery times, increasing quality, and decreasing inventory levels.

Simple Model B proposed in this section posits that *Production Process Risk* sources can cause low production and inventory levels. Therefore, the hypothesis for this model can formulated as follows:

H_1. *Production Process Risk* in the manufacturing industry have a negative direct impact on *Inventory* levels.

11.2.2.2 Validation of Simple Model B and Conclusions

As previously mentioned, this model relates latent variable *Production Process Risk* to latent variable *Inventory* benefits. The results from the validation of this hypothesized relationship are depicted in Fig. 11.5. As in the previous model, the estimated parameters are β, P, and R^2. As previously mentioned, for a relationship to be statistically significant in this research, it corresponding P value must be lower than 0.05.

Before the model can be interpreted, the latent variables must be validated. Table 11.2 reports the estimated latent variable coefficients.

According to the methodology followed for this research (see Chap. 9), the two factors have enough validity to remain in the model and thus interpret their

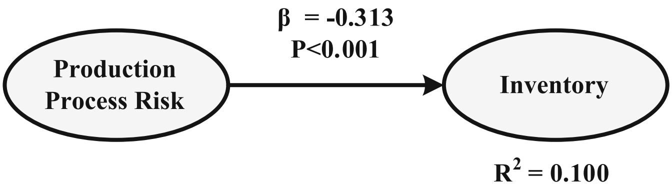

Fig. 11.5 Simple Model B evaluated: *Production Process Risk—Inventory*

Table 11.2 Latent variable validation—simple Model B

Coefficient	*Production Process Risk*	*Inventory*
R-Squared (R^2)		0.100
Adjusted R^2		0.094
Composite Reliability	0.895	0.924
Cronbach's Alpha Index (CAI)	0.842	0.876
Average Variance Extracted (AVE)	0.682	0.803
Full Collinearity VIF	1.002	1.002
Q-Squared (Q^2)		0.089

relationship. First, the values of R^2, adjusted R^2, and Q^2 are all higher than 0.02. Furthermore, the two latent variables report values higher than 0.7 in the composite reliability and Cronbach's alpha indices. Finally, the two AVE values are higher than 0.5 and the two VIF values are lower than 3.3.

Once the latent variables were validated, the ten model fit and quality indices were estimated (see Chap. 9) as follows:

– Average Path Coefficient (APC) = 0.313, $P < 0.001$
– Average R-Squared (ARS) = 0.100, $P = 0.034$
– Average Adjusted R-Squared (AARS) = 0.094, $P = 0.038$
– Average block VIF (AVIF) not available
– Average Full collinearity VIF (AFVIF) = 1.002, acceptable if ≤ 5, ideally ≤ 3.3
– Tenenhaus GoF (GoF) = 0.270, small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36
– Sympson's Paradox Ratio (SPR) = 1.000, acceptable if ≥ 0.7, ideally = 1
– R^2 Contribution Ratio (RSCR) = 1.000, acceptable if ≥ 0.9, ideally = 1
– Statistical Suppression Ratio (SSR) = 1.000, acceptable if ≥ 0.7
– Non-Linear Bivariate Causality Direction Ratio (NLBCDR) = 1.000, acceptable if ≥ 0.7

Since the latent variables were successfully validated and the model reports appropriate fit and quality indices, conclusions on the hypothesized relationship can be read as follows:

H_1. There is enough statistical evidence to claim that *Production Process Risk* in the manufacturing industry have a negative direct impact on *Inventory* benefits, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.313 standard deviations.

As regards the industrial implications of this relationship, we can conclude that *Inventory* levels altered due to *Production Process Risk* can ultimately lead to economic losses. If inventory levels are low, companies will be unable to meet its demand. Conversely, if inventory levels are high, companies will have too much product stored, more than they can sell.

11.2.3 Summary for Simple Models A and B

This book studies supply chain risks through three variables: supply risks, production process risks, and demand risks. The relationships between these risks and supply chain performance benefits produce eight possible effects. In other words, if each one of the simple relationships were to be modeled, 24 simple models would be analyzed in total. That said, due to content size restrictions, we provide only two exemplified simple models. However, the following paragraphs briefly discuss the remaining hypotheses that will be explored throughout the book. These hypothesized relationships pave the way for new research lines on supply chain performance and supply chain risk factors. Likewise, after the simple models, we propose two complex models. The first one discusses the impact of external risks on internal benefits, whereas the second one explores how supply chain risks factors are interrelated.

11.2.3.1 Simple Model Hypotheses

This section discusses the remaining 22 simple model hypotheses (for the first two, refer to the previous section). The first eight are developed with respect to product/services demand risks, whereas the following seven are proposed with respect to supply risks. Finally, the last seven hypotheses are concerned with production process risk.

The relationships between *Demand Risks* and supply chain performance benefits can be proposed as follows:

H_1. Product or services *Demand Risks* have a negative direct effect on *Delivery Times*.

H_2. Product or services *Demand Risks* have a negative direct effect on product/services *Quality*.

H_3. Product or services *Demand Risks* have a negative direct effect on production process *Flexibility*.

H_4. Product or services *Demand Risks* have a negative direct effect on *Customer Service*.

H_5. Product or services *Demand Risks* have a negative direct effect on production process *Agility*.

H_6. Product or services *Demand Risks* have a negative direct effect on supply chain *Financial Performance.*

H_7. Product or services *Demand Risks* have a negative direct effect on *Inventory* efficiency indices.

H_8. Product or services *Demand Risks* have a negative direct effect on *Transportation* benefits.

The remaining seven relationships between *Supply Risks* and supply chain performance benefits are formulated below. For the first relationship, refer to Figs. 11.3 and 11.4.

H_9. *Supply Risks* have a negative direct impact on product or services *Quality*.

H_{10}. *Supply Risks* have a negative direct impact on production process *Flexibility*.

H_{11}. *Supply Risks* have a negative direct impact on *Customer Service.*

H_{12}. *Supply Risks* have a negative direct impact on production process *Agility*.

H_{13}. *Supply Risks* have a negative direct impact on supply chain *Financial Performance.*

H_{14}. *Supply Risks* have a negative direct impact on *Inventory* efficiency indices.

H_{15}. *Supply Risks* have a negative direct impact on *Transportation* benefits.

Finally, the remaining relationships between *Production Process Risks* and supply chain benefits are analyzed through the following seven hypotheses. For this first hypothesis, consult Figs. 11.1 and 11.2 discussed earlier in the chapter.

H_{16}. *Production Process Risk* have a negative direct effect on *Delivery Times*.

H_{17}. *Production Process Risk* have a negative direct effect on *Quality*.

H_{18}. *Production Process Risk* have a negative direct effect on production process *Flexibility*.

H_{19}. *Production Process Risk* have a negative direct effect on *Customer Service*.

H_{20}. *Production Process Risk* have a negative direct effect on production process *Agility*.

H_{21}. *Production Process Risk* have a negative direct effect on supply chain *Financial Performance.*

H_{22}. *Production Process Risk* have a negative direct effect on *Transportation Benefits.*

11.2.3.2 Latent Variable Validation

This stage involves validating all the latent variables. As previously mentioned, three of them represent supply chain risks (i.e. supply risks, demand risks, production process risk), whereas eight represent supply chain performance benefits (i.e. transportation, inventory, financial performance, agility, flexibility, customer service, quality, and delivery times). Table 11.3 reports the latent variable coefficients estimated for the three supply chain risk variables. Note that none of the constructs reports R^2, adjusted R^2, or Q^2 values, since these variables are considered to be independent, and thus do not require a predictive validity test. As for the remaining latent variable coefficients, we can interpret the results as follows:

Table 11.3 Latent variable coefficients—*Supply Chain Risks*

Coefficients	*Supply Risks*	*Production Process Risk*	*Demand Risks*
Composite reliability	0.897	0.895	0.888
Cronbach's alpha index (CAI)	0.856	0.842	0.831
Average variance extracted (AVE)	0.635	0.682	0.665
Full collinearity VIF	1.620	1.014	1.536

- The three latent variables have enough internal validity, since the Cronbach's alpha and the composite reliability index have values higher than 0.7, the threshold.
- AVE values are higher than 0.5 in the three latent variables. Therefore, the constructs have enough convergent validity.
- VIF is lower than 3.3 in the three latent variables. Hence, the constructs do not have collinearity problems.

Table 11.4 reports the latent variable coefficients estimated on the eight supply chain performance latent variables. These constructs are considered to be dependent; hence, coefficients R^2, adjusted R^2, and Q^2 must be estimated for them. However, these coefficients are reported in Table 11.5, once the relationships between each supply chain performance latent variable and the supply chain risk latent variables have been analyzed and tested. Meanwhile, as Table 11.4 indicates, the eight latent variables representing supply chain performance benefits report Cronbach's alpha and composite reliability values higher than 0.6. Similarly, AVE reports values higher than 0.5 in the eight constructs, whereas VIF reports values lower than 3.3.

11.2.3.3 Hypotheses Validation

All the simple models were run to test the relationships between each supply chain risk variable and each supply chain performance benefit variable. The results of these statistical runs are reported in Table 11.5. As can be observed, every relationship has three estimated parameters; on the one hand, β stands for the magnitude of the effect, whereas P indicates the statistical significance of the relationship. On the other hand, R^2 indicates the amount of variance in the dependent latent variable that is explained by the independent latent variable. Finally, note that for a relationship to be statistically significant, its corresponding P value must be lower than 0.05.

The results reported in the table can be discussed as follows:

- All the relationships report negative β values, implying that all supply chain risk factors minimize supply chain performance benefits.

Table 11.4 Latent variable coefficients—*Supply Chain Performance*

Coefficient	*Transportation*	*Inventory*	*Financial Performance*	*Agility*	*Customer Service*	*Flexibility*	*Quality*	*Delivery Times*
Composite Reliability	0.848	0.924	0.837	0.909	0.857	0.85	0.835	0.84
Cronbach's Alpha Index (CAI)	0.73	0.876	0.705	0.874	0.75	0.764	0.605	0.618
Average Variance Extracted (AVE)	0.652	0.803	0.634	0.666	0.667	0.589	0.717	0.724
Full Collinearity VIF	1.391	1.758	1.515	2.544	2.063	1.974	1.354	1.739

Table 11.5 Summary of simple models (*Supply Chain Risks—Supply Chain Performance*)

To	From		
	Demand Risks	*Supply Risks*	*Production Process Risk*
Delivery Times	$\beta = -0337$ ($P < 0.01$) $R^2 = 0.151$	***$\beta = -0.434$ ($P < 0.01$) $R^2 = 0.188$***	$\beta = -0.225$ ($P < 0.01$) $R^2 = 0.051$
Quality	$\beta = -0.390$ ($P < 0.01$) $R^2 = 0.152$	$\beta = -0.373$ ($P < 0.01$) $R^2 = 0.139$	$\beta = -0.313$ ($P < 0.01$) $R^2 = 0.098$
Flexibility	$\beta = -0.384$ ($P < 0.01$) $R^2 = 0.148$	$\beta = -0.341$ ($P < 0.01$) $R^2 = 0.138$	$\beta = -0.176$ ($P < 0.01$) $R^2 = 0.054$
Customer Service	$\beta = -0.384$ ($P < 0.01$) $R^2 = 0.147$	$\beta = -0.403$ ($P < 0.01$) $R^2 = 0.163$	$\beta = -0.283$ ($P < 0.01$) $R^2 = 0.088$
Agility	$\beta = -0.337$ ($P < 0.01$) $R^2 = 0.113$	$\beta = -0.391$ ($P < 0.01$) $R^2 = 0.153$	$\beta = -0.296$ ($P < 0.01$) $R^2 = 0.080$
Financial Performance	$\beta = -0.385$ ($P < 0.01$) $R^2 = 0.148$	$\beta = -0.276$ ($P < 0.01$) $R^2 = 0.076$	$\beta = -0.233$ ($P < 0.01$) $R^2 = 0.031$
Inventory	$\beta = -0.261$ ($P < 0.01$) $R^2 = 0.068$	$\beta = -0.361$ ($P < 0.01$) $R^2 = 0.131$	***$\beta = -0.134$ ($P < 0.01$) $R^2 = 0.10$***
Transportation	$\beta = -0.335$ ($P < 0.01$) $R^2 = 0.112$	$\beta = -0.345$ ($P < 0.01$) $R^2 = 0.116$	$\beta = -0.262$ ($P < 0.01$) $R^2 = 0.051$

- All the values of P are lower than 0.01. This implies that all the relationships are statically significant and the negative impacts of supply chain risk factors are negative.
- All the independent latent variables can explain a part of the variance of the dependent latent variables (i.e. supply chain performance benefits), even though the direct effect is negative.
- The analysis results from the two models discussed in the beginning of the chapter appear in bold and italicized. However, their corresponding hypotheses are not discussed below.

Following the results reported in Table 11.5, the validated hypotheses read as follows:

H_1. There is enough statistical evidence to claim that *Demand Risks* have a negative direct effect on *Delivery Times*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.337 standard deviations.

H_2. There is enough statistical evidence to claim that *Demand Risks* have a negative direct effect on *Quality*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.390 standard deviations.

H_3. There is enough statistical evidence to claim that *Demand Risks* have a negative direct effect on production process *Flexibility*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.384 standard deviations.

H_4. There is enough statistical evidence to claim that *Demand Risks* have a negative direct impact on *Customer Service*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.337 standard deviations.

H_5. There is enough statistical evidence to claim that *Demand Risks* have a negative direct impact on production process *Agility*, since when the former latent variable increases by one standard deviation, the second latent variable decreases by 0.385 standard deviations.

H_6. There is enough statistical evidence to claim that *Demand Risks* have a negative direct impact on *Financial Performance*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.337 standard deviations.

H_7. There is enough statistical evidence to claim that *Demand Risks* have a negative direct impact on *Inventory* efficiency levels, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.261 standard deviations.

H_8. There is enough statistical evidence to claim that *Demand Risks* have a negative direct impact on *Transportation* benefits, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.335 standard deviations.

As regards the relationship between *Supply Risks* and supply chain performance benefits, the following conclusions can be proposed. Note that one of these conclusions was discussed earlier in this chapter and is not listed below.

H_9. There is enough statistical evidence to claim that *Supply Risks* have a negative direct impact on product *Quality* benefits, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.373 standard deviations.

H_{10}. There is enough statistical evidence to claim that *Supply Risks* have a negative direct impact on production process *Flexibility*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.341 standard deviations.

H_{11}. There is enough statistical evidence to claim that *Supply Risks* have a negative direct impact on *Customer Service*, since when the former increases by one standard deviation, the latter decreases by 0.403 standard deviations.

H_{12}. There is enough statistical evidence to claim that *Supply Risks* have a negative direct impact on production process *Agility*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.391 standard deviations.

H_{13}. There is enough statistical evidence to claim that *Supply Risks* have a negative direct impact on supply chain *Financial Performance*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.276 standard deviations.

H_{14}. There is enough statistical evidence to claim that *Supply Risks* have a negative direct impact on *Inventory* efficiency levels, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.361 standard deviations.

H_{15}. There is enough statistical evidence to claim that *Supply Risks* have a negative direct impact on *Transportation* benefits, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.345 standard deviations.

Finally, to analyze the effects of production process risks on supply chain performance benefits, we propose eight conclusions. One of them was discussed earlier in this chapter and thus is not listed below:

H_{16}. There is enough statistical evidence to claim that *Production Process Risk* have a negative direct impact on *Delivery Times*, since when the former increases by one standard deviation, the second latent variable decreases by 0.225 standard deviations.

H_{17}. There is enough statistical evidence to claim that *Production Process Risk* have a negative direct impact on product *Quality*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.313 standard deviations.

H_{18}. There is enough statistical evidence to claim that *Production Process Risk* have a negative direct impact on production process *Flexibility*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.176 standard deviations.

H_{19}. There is enough statistical evidence to claim that *Production Process Risk* have a negative direct impact on *Customer Service*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.283 standard deviations.

H_{20}. There is enough statistical evidence to claim that *Production Process Risk* have a negative direct impact on production process *Agility*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.296 standard deviations.

H_{21}. There is enough statistical evidence to claim that *Production Process Risk* have a negative direct impact on supply chain *Financial Performance*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.222 standard deviations.

H_{22}. There is enough statistical evidence to claim that *Production Process Risk* have a negative direct impact on *Transportation* benefits, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.262 standard deviations.

11.2.3.4 Summary of Simple Risk-Performance Models

According to the results reported in Table 11.5, we can conclude the following:

- *Demand Risks* have the largest negative impact on *Quality*, as $\beta = 0.39$. However, the impact is also high on production process *Flexibility* and *Customer Service*. Such results imply that manufacturing companies with little room for manoeuvre experience low quality and customer satisfaction levels when they are unable to meet demand.
- *Demand Risks* have the least negative, but still statistically significant, impact on *Inventory* efficiency levels, as $\beta = 0.261$.
- *Supply Risks* cause the highest negative impact on *Delivery Times*, since $\beta = 0.434$. This is the highest estimation of all. Such results imply that if suppliers are unable to timely deliver raw materials, neither will manufacturers be able to deliver their products on time.
- *Supply Risks* cause the least negative impact on supply chain *Financial Performance*, since $\beta = 0.276$. Such information suggests that when suppliers do not deliver the correct raw materials on time, manufacturers manage to solve the problem through other strategies, such as production agility.
- *Production Process Risk* have the largest negative impact on *Quality* benefits. This implies that miscalibrated and unmaintained machinery and equipment adversely affect both the material flow and the manufacturers' ability to comply with product technical requirements.
- Finally, *Production Process Risk* cause the least negative impact on *Inventory* efficiency levels and *Flexibility.* Such results imply that production process failures lead to insufficient or unnecessary high inventory levels. Consequently, manufacturers have limited flexibility when adopting supply chain improvement strategies.

11.3 Complex Risk Models

The simple models presented earlier discussed and analyzed the direct relationship between each supply chain risk factor and each supply chain performance benefit. Nevertheless, these models only explain risk-benefit relationships superficially. To gain a comprehensive and holistic understanding of how multiple supply chain risk factors and performance benefits are interrelated, more complex models must be developed.

11.3.1 *Complex Model C:* External Risks—Internal Benefits

The first complex model is visually introduced in Fig. 11.6. The model integrates four latent variables: *Supply Risks*, *Demand Risks, Delivery Times,* and *Inventory*. The first two are considered independent, whereas the remaining two are dependent variables. Similarly, the model illustrates all the possible relationships between them.

11.3.1.1 Hypotheses for Complex Model C: *External Risks—Internal Benefits*

This model proposes six research hypotheses to be tested statistically. They are supported by previous research works and will be used in this chapter to explore the interrelationship between external supply chain risk factors and internal supply chain performance benefits.

Demand Risks are associated with supply chain activities, such as production distribution and demand forecast. Such factors can lead to production bottlenecks, high inventory levels, or inefficient capacity utilization (Thun and Hoenig 2011). Measures of demand assessment are usually implemented to improve demand planning and inventory management, increase customer satisfaction, and obtain the desired benefits. In this sense, demand management is key to preventing both production errors and supply errors (Bhattacharyya et al. 2010; Lockamy and McCormack 2010).

Sometimes, perceived *Demand Risks* and *Supply Risks* are referred to as operational risks. They result from failures in processes, human resources, and systems, and they affect product quality and delivery times (Chen et al. 2013). Undoubtedly, *Demand Risks* can be mitigated and even prevented from the supply stage through

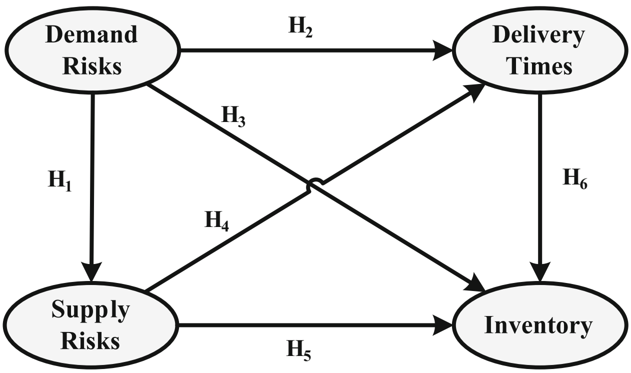

Fig. 11.6 Complex Model C proposed: *External Risks—Internal Benefits*

efficient demand forecast systems (Huber et al. 2017). *Demand* changes imply *Supply* changes that might be difficult to deal with, such as raw material scarcity (Kourentzes et al. 2017). Therefore, considering the impact of *Demand Risks* on *Supply Risks*, the first hypothesis of the model can be read as follows:

H_1. In supply chain environments, *Demand Risks* have a negative direct impact on *Supply Risks.*

Demand Risks are one of the major risk factors affecting *Delivery Times.* When change in demand occurs, companies should negotiate new *Delivery Times* with their customers, since production capacity is usually planned, and there are rarely slack times to make adjustments in machinery (Mosaad et al. 2018). Therefore, it is important that companies do not only strive to mitigate *Demand Risks*, but also work in the flexibility of its production process and supply chain (Altendorfer 2017). Similarly, product cost must include demand risk to cover the additional costs incurred (e.g. overtime pay) to deliver the new product on time (Alonso-Ayuso et al. 2017). Following this discussion, the second research hypothesis of model C can be proposed as follows:

H_2. In supply chain environments, *Demand Risks* have a direct impact on *Delivery Times.*

Risk factors such as *Demand* fluctuations affect both relationships with suppliers and raw material availability (Wang et al. 2016). As Schmenner (2004b) points out, production process productivity declines or is disrupted when raw material availability is altered. Consequently, the supply chain is affected (Chen et al. 2013; Schmenner 2004a). In this sense, the relationship between *Demand* and *Inventories* is frequently studied. For instance, Wagner and Bode (2008); (Wagner Stephan and Bode 2011) claim that as *Supply Risks* and *Demand Risks* increase, supply chain performance decreases. This underperformance is usually visible through indicators such as product quality, customer services, delivery times, inventory efficiency levels, and production costs. Therefore, in the manufacturing industry, the third research hypotheses of model C is proposed as follows:

H_3. In supply chain environments, *Demand Risks* have a direct impact on *Inventory* levels.

Inadequate supply has a serious impact on product or service deliveries. It can either compromise *Delivery Times* or unnecessarily increase production costs (Vahidi et al. 2018). The relationship between these two variables has been insightfully explored in the manufacturing industry. In their research, Avelar-Sosa et al. (2014) assessed the impact of perceived *Demand Risks* on *Suppliers*, and consequently, on production *Flexibility* and *Customer Service*, including *Delivery Times*. The authors found out that supply chain communication is a key to on time decision-making and corrective actions for *Delivery Time* problems. Similarly, Ho et al. (2010) conducted a literature review and concluded that *Supply Risk* minimization strategies and resolutions should focus on four major areas: quality, *Delivery Times*, customer service, and technological capacity. In this sense, the fourth research hypothesis for model C is stated below:

H_4. In supply chain environments, *Supply Risks* have a direct impact on *Delivery Times.*

Supply shortages do not only affect raw material *Inventory* levels, but also the production process (Bhattacharyya and Guiffrida 2015). Hong et al. (2017) studied this phenomenon and concluded that *Suppliers* must be evaluated in order to determine their reliability. Similarly, to Türk et al. (2017), supplier integration is a significant key to supply chain risks minimization. Likewise, vv (Giri 2011; Yan and Liu 2009), advise manufacturers to work with two suppliers, not only one, if there are potential reliability risks. In fact, modern companies often rely on this technique to decrease dependency among supply chain partners. In order to explore the relationship between *Supply Risks* and *Inventory* efficiency levels, the fifth working hypothesis for model C is proposed below:

H_5. In supply chain environments, *Supply Risks* have a direct impact on *Inventory* benefits.

In their research, Song et al. (2009) studied the effects of *Delivery Times* variability on *Inventory* policies and total production costs. Likewise, Chaharsooghi and Heydari (2010) simulated a multilevel supply chain environment to determine the impact of *Delivery Times* on *Inventory* levels and product availability. From a similar perspective, other authors claim that delivery delays adversely affect corporate economic performance and can be the result of *Transportation* risks, which are a *Supply Risk* factor (Arıkan et al. 2014). Finally, other studies point out that supply *Delivery Times* minimization and *Delivery Times* variability minimization can have a positive impact on *Inventory levels* without affecting customer service (Chopra et al. 2004; Izar Landeta et al. 2015). In this sense, the sixth research hypotheses proposed for Model C can be read as follows:

H_6. In supply chain environments, *Delivery Times* benefits have a direct impact on *Inventory* benefits.

The six aforementioned hypotheses, and Model C as a whole (see Fig. 11.6), suggest that the interaction among the three major supply chain risk factors (i.e. *Demand Risks, Production Process Risk, Supply Risks*) causes variability in supply chain performance benefits (Germain et al. 2008). Similarly, the model suggests that both *Supply Risks* and *Production Process Risk* have effects on *Delivery Times* and *Inventory* levels as two supply chain performance indicators. In conclusion, the goal of Model C is to assess supply chain performance with respect to the influence of three major supply chain risk factors.

11.3.1.2 Results of Complex Model C: *External Risks—Internal Risks*

The model introduced in Fig. 11.6 is tested as a structural equation model, whose evaluation results are depicted in Fig. 11.7. Notice that parameter values in complex models, such as model C, can differ from those values obtained in the simple models, even though the same relationship is concerned. This is due to the fact that in complex models, multiple variables are taken into account.

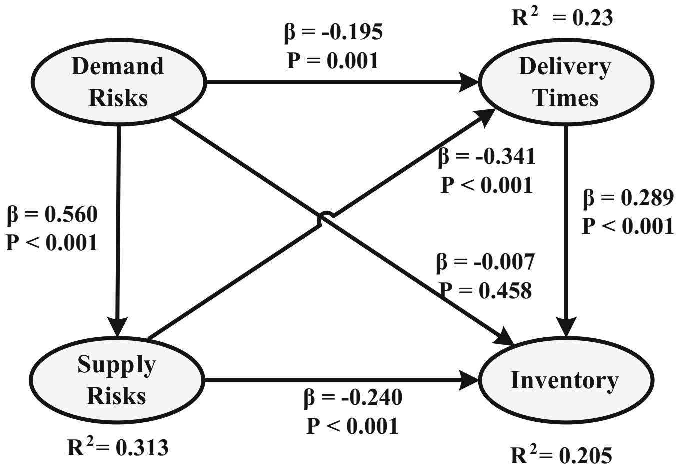

Fig. 11.7 Complex Model C evaluated: *External Risks—Internal Benefits* (performance)

- Five relationships are statistically significant since their corresponding *P* values are lower than 0.01.
- Four relationships have negative β values, indicating that risk latent variables have negative effects on performance benefit variables. This behavior was previously demonstrated for the simple models.
- All the dependent latent variables have an R^2 value higher than 0.02, the lowest possible value.
- The relationship between *Demand Risks* and *Inventory* benefits is not statistically significant since *P* value = 0.458. However, it will remain in the model for further analyses.

11.3.1.3 Efficiency Indices of Complex Model C: *External Risks—Internal Benefits*

In order to validate the efficiency of the model, the following indices were computed as discussed in the methodology chapter:

- Average Path Coefficient (APC) = 0.272, $P < 0.001$
- Average R-Squared (R^2) (ARS) = 0.249, $P < 0.001$
- Average Adjusted R-Squared (AARS) = 0.242, $P < 0.001$
- Average block VIF (AVIF) = 1.493, acceptable if ≤ 5, ideally ≤ 3.3
- Average full collinearity VIF (AFVIF) = 1.417, acceptable if ≤ 5, ideally ≤ 3.3
- Tenenhaus GoF (GoF) = 0.414, small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36
- Sympson's Paradox Ratio (SPR) = 1.000, acceptable if ≥ 0.7, ideally = 1
- R-Squared Contribution Ratio (RSCR) = 1.000, acceptable if ≥ 0.9, ideally = 1

- Statistical Suppression Ratio (SSR) = 1.000, acceptable if ≥ 0.7
- Non-Linear Bivariate Causality Direction Ratio (NLBCDR) = 1.000, acceptable if ≥ 0.7

As can be observed, on average, all the β parameters of Model C are statistically significant since APC = 0.271. Furthermore, both ARS and AARS are higher than 0.2—the lowest acceptable value—and report $P < 0.001$. On the other hand, model collinearity as expressed by AVIF and AFVIF indices is significantly lower than 3.3, the highest possible value, whereas the Tenenhaus GoF is equal to 0.414, which indicates a good model fit. Finally, according to the remaining indices, the model is free from directionality problems in the hypotheses.

11.3.1.4 Latent Variable Coefficients in Complex Model C

The seven coefficients estimated to assess the validity of the latent variables are thoroughly discussed in the methodology chapter. Table 11.6 reports the results of this validation process, from which it is possible to conclude the following:

- The three independent latent variables have enough parametric predictive validity as expressed by R^2 and adjusted R^2 coefficients, which are all higher than 0.02. Likewise, since the values of Q^2 are all higher than 0.2 and similar to their corresponding R^2 values, it is concluded that the model has enough non-parametric predictive validity.
- All the latent variables have enough internal validity, since the CAI and composite reliability indices are all higher than 0.7.
- All the latent variables have enough convergent validity, since AVE reports values higher than 0.5, being 0.555 the lowest value in latent variable *Supply Risks.*
- There seem to be no internal collinearity problems in the latent variables, as all the VIF values are lower than 3.3, the highest possible value. In this sense, latent variable *Supply Risks* reports the highest value (VIF = 1.604).

Table 11.6 Latent variable validation in complex Model C: *External Risks—Internal Benefits*

Coefficients	*Demand Risks*	*Supply Risks*	*Delivery Times*	*Inventory*
R-Squared (R^2)		0.313	0.229	0.205
Adjusted R^2		0.31	0.222	0.194
Composite reliability	0.888	0.879	0.84	0.924
Cronbach's alpha index (CAI)	0.831	0.832	0.618	0.876
Average variance extracted (AVE)	0.665	0.555	0.724	0.803
Full collinearity VIF	1.449	1.604	1.394	1.22
Q-Squared (Q^2)		0.312	0.23	0.208

In conclusion, both the model and its latent variables report adequate validity. Therefore, the relationships can be interpreted and analyzed accordingly. The first step of this analysis involves interpreting the direct effects in these relationships.

11.3.1.5 Direct Effects

As previously mentioned, the goal of analyzing the direct effects between latent variables is either to accept or to reject the proposed hypotheses or hypothesized relationships. As Fig. 11.7 indicates, every relationship is associated with a β value and a P value. For a relationship to be statistically significant at a 95% confidence level, its corresponding P value must be lower than 0.05.

H_1. There is enough statistical evidence to claim that, in supply chain environments, *Demand Risks* have a direct impact on *Supply Risks*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.560 standard deviations. Such results imply that if demand forecast is accurate, suppliers perceive significantly less risk and are able to meet the needs of the manufacturers on time.

H_2. There is enough statistical evidence to claim that in supply chain environments, perceived *Demand Risks* have a direct impact on *Delivery Times*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.195 standard deviations.

H_3. There is not enough statistical evidence to claim that, in supply chain environments, perceived *Demand Risks* have a direct impact on *Inventory* levels, since the P value is higher than 0.05. In other words, the data gathered is not enough to prove the feasibility of this relationship.

H_4. There is enough statistical evidence to affirm that, in supply chain environments, perceived *Supply Risks* have a negative direct impact on *Delivery Times*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.341 standard deviations. Such results indicate that raw material transformation largely depends on raw material delivery times.

H_5. There is enough statistical evidence to affirm that, in supply chain environments, perceived *Supply Risks* have a negative direct impact on *Inventory* levels, since when the first latent variable increases by one standard deviation, the second latent variable decreases by 0.240 standard deviations. This relationship complements the previous relationship in the sense that inventory levels of both raw materials and products depend to a great extent on raw material availability. Moreover, as supply chain communication and coordination decrease, inventory efficiency decreases.

H_6. There is enough statistical evidence to affirm that, in supply chain environments, *Delivery Times* have a positive direct impact on *Inventory* benefits, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.289 standard deviations. The validity of this relationship confirms that as delivery times are met, inventory levels are appropriate.

11.3.1.6 Effect Sizes

In SEM, the variability of a dependent latent variable is expressed by the R^2 coefficient; however, when two or more independent latent variables explain a dependent latent variable, the R^2 must be decomposed to determine the percentage of variance that originates from each exogenous variable. This portion of variance is commonly referred to as an effect size. As Fig. 11.7 illustrates, the two benefit variables are affected by more than one independent latent variable. In this sense, Table 11.7 reports the effect sizes for Model C, where the R^2 is decomposed. Such results allow proposing the following conclusions:

- Latent variable *Demand Risks* has direct effects on the three remaining latent variables, showing values of β = 0.313, 0.154, and 0.114. Therefore, this latent variable is located in the top-left corner of the model.
- *Demand Risks* explains the total explained variance of *Supply Risks*, implying that as demand uncertainty increases, supply-related problems are more likely to arise. In other words, *Demand Risks* lead to *Supply Risks* and supply chain underperformance.
- Together, two latent variables explain 23% of the variance of *Delivery Times* (R^2 = 0.23). Namely, *Demand Risks* explains 7.6%, whereas *Supply Risks* explains 15.4%.
- Together, three latent variables explain 20.5% of the variance of *Inventory*. Latent variable *Demand Risks* explains the lowest percentage (0.2%), *Supply Risks* explains 8.9%, and *Delivery Times* is responsible for 11.4%. Such results indicate that in order to gain *Inventory* benefits, *Delivery Time* benefits should be obtained first. Notice that this effect size is the largest.

11.3.1.7 Sum of Indirect Effects

Indirect relationships between two latent variables occur through mediator variables. Hence, these relationships involve two or more model segments. Indirect effects are calculated to determine how indirect variables affect a relationship and to identify the implications for the phenomenon that is being studied. For Model C, Table 11.8 reports the effect sizes (ES) of the indirect relationships found between the latent variables.

Table 11.7 Effect sizes in complex Model C

To	From			R^2
	Demand Risks	*Supply Risks*	*Delivery Times*	
Supply Risks	0.313			0.313
Delivery Times	0.076	0.154		0.230
Inventory	0.002	0.089	0.114	0.205

Table 11.8 Sum of indirect effects in complex Model C

To	From	
	Demand Risks	*Supply Risks*
Delivery Times	−0.191 ($P < 0.001$) ES = 0.074	
Inventory	−0.245 ($P < 0.001$) ES = 0.064	−0.098 ($P = 0.017$) ES = 0.036

According to these results, it is possible to propose the following conclusions:

- The three indirect relationships, and thus their corresponding effects, are significant at a 95% confidence level, since all the *P* values are lower than 0.05.
- The indirect relationship between latent variables *Demand Risks* and *Inventory* reports the largest effect, being $\beta = 0.245$.
- The indirect relationship between latent variables *Supply Risks* and *Inventory* reports the smallest effect, as $\beta = 0.098$.
- Overall, the explanatory power of the indirect effects is low. Together, the three effects explain merely 20% of the variability of the latent variables. The largest effect size involves latent variables *Demand Risks* and *Inventory* benefits, being ES = 0.074.

11.3.1.8 Total Effects

The total effects of a relationship between two latent variables are the sum of the direct and indirect effects. Table 11.9 reports the total effects found in the relationships between latent variables. Such results can be interpreted as follows:

- The model has six total effects, two of them are positive and two are negative.
- All the total effects are statistically significant at a 95% confidence level since the *P* values are lower than 0.05.
- The largest total effects can be perceived in the relationship between *Demand Risks* and *Supply Risks*, as $\beta = 0.560$. This relationship also has the largest explanatory power as indicated by ES.

Table 11.9 Sum of total effects in complex Model C

To	From		
	Demand Risks	*Supply Risks*	*Delivery Times*
Supply Risks	0.560 ($P < 0.001$) ES = 0.313		
Delivery Times	−0.385 ($P < 0.001$) ES = 0.150	−0.341 ($P < 0.001$) ES = 0.154	
Inventory	−0.252 ($P < 0.001$) ES = 0.066	−0.338 ($P < 0.001$) ES = 0.125	0.289 ($P < 0.001$) ES = 0.114

- The relationship between *Demand Risks* and *Delivery Times* has the second largest total effects, as $\beta = -0.385$.
- The relationship between *Demand Risks* and *Inventory* reports the smallest effect, being $\beta = -0.252$, and also the largest explanatory power (ES = 0.066).

11.3.1.9 Final Conclusions of Complex Model C

The tests and analyses conducted on Fig. 11.6 of Model C provided insightful results regarding the impact of external risk factors on internal supply chain performance benefits. The final conclusions as regards this model can be proposed as follows:

- *Demand* forecast is a source of subsequent risks, especially *Supply Risks.* According to our results, the relationship between *Demand Risks* and *Supply Risks* has one of the largest effects, as indicated by the value of β. In this sense, it is important for company managers to ensure accurate *Demand* forecasts in order to minimize potential risks along the supply chain.
- The performance of *Delivery Times* is affected by both *Demand Risks* and *Supply Risks,* yet according to the β values, the latter has a much larger direct impact. Such results indicate that if managers wish to comply with *Delivery Times*, they must pay close attention to potential *Supply Risks.*
- *Demand Risks* do not have a significant direct effect on *Inventory*, yet the indirect effect is significant and negative. In other words, *Supply Risks* and *Delivery Times* are important mediator variables when it comes to ensuring appropriate *Inventory* levels.

11.3.2 *Complex Model D:* Interrelations Among Supply Chain Risk Variables

All the previous models have managed to demonstrate that the three major supply chain risk factors have negative direct effects on supply chain performance. Additionally, model D has proved that *Demand Risks* have a positive impact on *Supply Risks*. Nevertheless, it remains unclear how and to what extent the three supply chain risk factors are interrelated and what these interactions imply. To address these questions, the following model, Model D, only integrates supply chain risk factors. The model takes into account the temporality of the events and thus considers the order of risk factors as follows: *Demand Risks* lead to *Supply Risks*, which in turn lead to *Production Process Risk*.

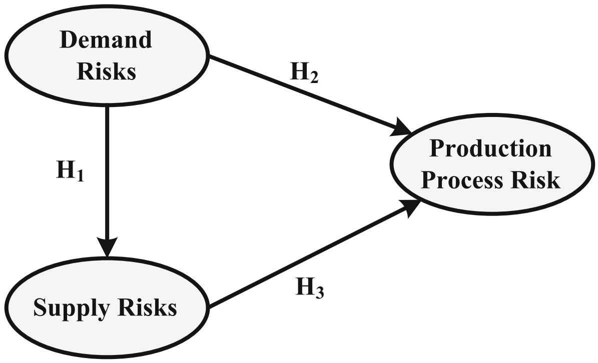

Fig. 11.8 Initial complex Model D proposed: *interrelations among supply chain risks variables*

The three latent variables of Model D can be listed below:

- *Demand Risks*
- *Supply Risks*
- *Production Process Risk*

Model D is visually represented in Fig. 11.8. As can be observed, three research hypotheses are proposed to relate the latent variables. Notice that the relationship between *Demand Risks* and *Supply Risks* was analyzed in the previous model; however, relationships between two latent variables can be altered as new latent variables interact in the model. In this sense, it will not be surprising to find different results in this model for the same relationship. Finally, the ultimate goal of this model is to determine whether *Demand Risks* cause risks in the other factors (i.e. supply and production processes). Such results would confirm the supposition that process risks are not only due to suppliers and internal activities.

11.3.2.1 Hypotheses Complex Model D: *Interrelations Among Supply Chain Risks Variables*

The hypotheses depicted in Fig. 11.8 must be statistically tested, yet their proposal was supported by the literature. In this sense, *Supply Risks* and *Demand Risks* are commonly referred to as external risks sources, whereas *Production Process Risk* are external sources. Risks in production processes result from the interaction among those external risk sources that alter the variability of the system (Jüttner et al. 2003).

Change in *Demand* implies change in *Supply*, as increased orders require more raw materials (Yan et al. 2018). However, sometimes *Demand Risks* can also be the result of special product discounts, from which customers take advantage and purchase more (Singh 2014; Wu et al. 2017). As Sucky (2009) claims, *Demand Risks* should be efficiently managed since *Demand* variability affects the whole supply chain, including suppliers and production processes. In other words, perceived risks increase as we move along the chain. Amid *Demand* changes, manufacturers must be able to negotiate new prices with customers to address additional expenses incurred, especially in terms of raw materials (Zheng and Negenborn 2015). In this sense, to mitigate and respond quickly to the effects of unexpected *Demand* changes, supply chain partners must communicate efficiently through the several communication systems that are at their disposal (Quigley et al. 2018). Therefore, to test the relationship between *Demand Risks* and *Supply Risks*, the following hypothesis is proposed:

H_1. In supply chain environments, *Demand Risks* have a positive direct effect on *Supply Risks*.

Demand Risks have an impact not only on *Supply Risks*, but also on the production process. Production systems have a precise production capacity installed; therefore, to face an unexpected change in demand, manufacturers are forced to make adjustments in the production machinery, reorganize its human resources, and assume unexpected additional production costs (Jian et al. 2015).

Modern studies on supply chain performance have managed to model the relationship between *Demand Risks* and *Supply Risks* from various perspectives. For instance, Jian et al. (2015) analyzed the two variables and assessed their impact on final production costs. Likewise, other models have provided a clearer understanding of this relationship by testing it under multiple different scenarios, considering aspects such as fixed costs, price sensitivity, and product quantity (Johansson et al. 2016). On the other hand, scientists have focused on determining *Demand* behavior through sales forecasting methods in order to facilitate managerial decision-making (Tanaka et al. 2012). Additionally, they have studied quasi-fixed cyclic production schemes for multiple products with stochastic *Demand* (Briskorn et al. 2016). In this sense, to test the relationship between *Demand Risks* and *Production Process Risk*, the second research hypothesis for this model can be proposed as follows:

H_2. In supply chain environments, *Demand Risks* have a positive direct effect on *Production Process Risk*.

In their work, Chen et al. (2013) studied operational risk mitigation. Specifically, the authors stated that *Supply Risks* and *Demand Risks* were either positively or negatively related to *Production Process Risk*. This risk analysis was the basis of another study, conducted by Avelar-Sosa et al. (2014), who developed a structural equation model to validate such relationship. As main findings, Avelar-Sosa et al. (2014) reported that the relationship was statistically significant. Finally, scientists have also sought to relate *Demand Risks* and *Supply Risks* with corporate sustainability (Torres-Ruiz and Ravindran 2018). That said, since *Supply Risks* will always be present, they must be constantly assessed and monitored to prevent potential *Production Process Risk* (Mokhtar et al. 2017). Similarly, contract clauses must explicitly state the consequences of little or no compliance from the part of either suppliers or manufacturers (He et al. 2017). In this sense, the third research hypothesis of Model D can read as follows:

H_3. In a supply chain environment, *Supply Risks* have a positive direct effect on *Production Process Risk*.

11.3.2.2 Results of Complex Model D: *Supply Chain Risk Variables*

The model proposed in Fig. 11.8 was tested as discussed in the methodology chapter, using structural equation modeling. The results are introduced in Fig. 11.9 and can be interpreted as follows:

- Two out of the three relationships are statistically significant at a 95% confidence level, since the *P* value is lower than 0.05.
- In this model, the relationship between *Demand Risks* and *Supply Risks* has the same contribution as in the previous model (Fig. 11.6).
- The model depicts the interaction among the three supply chain risk factors but does not take into account any supply chain performance benefit. This will be performed in further chapters.

11.3.2.3 Efficiency Indices of Complex Model D: *Interrelations Among Supply Chain Risk Variables*

Ten model fit and quality indices were calculated to test the model's efficiency and provide accurate inferences on the hypotheses, and the results from this are:

- Average Path Coefficient (APC) = 0.230, $P < 0.001$
- Average *R*-Squared (R^2) (ARS) = 0.164, $P = 0.003$

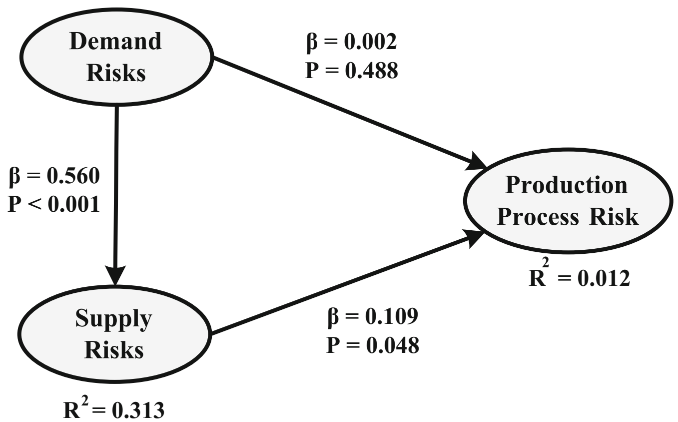

Fig. 11.9 Complex Model D evaluated: *interrelations among supply chain risks variables*

- Average Adjusted R-Squared (AARS) = 0.158, P = 0.004
- Average block VIF (AVIF) = 1.190, acceptable if ≤ 5, ideally ≤ 3.3
- Average Full collinearity VIF (AFVIF) = 1.277, acceptable if ≤ 5, ideally ≤ 3.3
- Tenenhaus GoF (GoF) = 0.323, small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36
- Sympson's Paradox Ratio (SPR) = 1.000, acceptable if ≥ 0.7, ideally = 1
- R-Squared Contribution Ratio (RSCR) = 1.000, acceptable if ≥ 0.9, ideally = 1
- Statistical Suppression Ratio (SSR) = 1.000, acceptable if ≥ 0.7
- Non-Linear Bivariate Causality Direction Ratio (NLBCDR) = 1, acceptable if ≥ 0.7.

According to the results, the model has adequate predictive validity, since both ARS and AARS are higher than 0.02, and their corresponding P values are lower than 0.05. Furthermore, both AVIF and AFVIF report values lower than 3.3, which confirms that the model is free from collinearity problems. As for the Tenenhaus GoF, its value implies a good, but not high, goodness of fit index. As mentioned in the methodology chapter, the Tenenhaus GoF measures the extent to which gathered data fit the model. Its value ranges from 0.25 to 0.36. Finally, according to the remaining indices, the model hypotheses are free from directionality problems.

11.3.2.4 Latent Variable Coefficients in Complex Model D

Once the model fit and quality indices were calculated, the model latent variables were individually tested as discussed in the methodology chapter. Table 11.10 reports the result from this validation process. As can observed, latent variable *Supply Risks* has enough predictive validity, since R^2 and R^2 values are higher than 0.02.

Conversely, latent variable *Production Process Risk* does not have enough predictive validity, since its corresponding R^2 and R^2 values are lower than 0.02. Such results might be due to the fact that both *Demand Risks* and *Supply Risks* are

Table 11.10 Latent variable validation in complex Model D: *interrelations among supply chain risks variables*

Coefficient	*Demand Risks*	*Supply Risks*	*Production Process Risk*
R-Squared (R^2)		0.313	0.015
Adjusted R-Squared		0.31	0.006
Composite Reliability	0.888	0.879	0.895
Cronbach's Alpha Index (CAI)	0.831	0.832	0.842
Average Variance Extracted (AVE)	0.665	0.555	0.682
Full Collinearity VIF	1.414	1.412	1.003
Q-Squared (Q^2)		0.312	0.016

external risk factors, whereas *Production Process Risk* are internal factors, which makes them more manageable.

As for internal validity, the three latent variables report CAI and composite reliability values higher than 0.7, the threshold. Likewise, AVE values are all higher than 0.5 and indicate that the latent variables have enough convergent validity, whereas VIF results, all lower than 3.3, free the latent variables from collinearity problems.

11.3.2.5 Direct Effects

The direct effects were calculated to validate the hypotheses proposed in Fig. 11.8 and tested as depicted in Fig. 11.9. As in previous cases, the hypotheses have a β and a P value associated. In order for a relationship to be significant, its corresponding P value must be lower than 0.05. The conclusions with respect to the direct effects can be proposed below:

H_1. There is enough statistical evidence to claim that, in supply chain environments, *Demand Risks* have a positive direct effect on *Supply Risks*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.56 standard deviations. This hypothesis was also validated in the previous model.

H_2. There is not enough statistical evidence to claim that, in supply chain environments, *Demand Risks* have a positive direct effect on *Production Process Risk*, since the corresponding P value is higher than 0.05 (P = valor 0.488).

H_3. There is enough statistical evidence to claim that, in supply chain environments, *Supply Risks* have a positive direct effect on *Production Process Risk*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.109 standard deviations.

The industrial implications of these results can be listed below:

- Perceived *Demand Risks* can lead to both *Supply Risks* and *Production Process Risk*. Therefore, it is important that managers clearly identify market trends and potential customers in order to accurately forecast and communicate in real time demand to the subsequent chain stages.

Surprisingly, *Demand Risks* do not have a direct effect on *Production Process Risk.* This phenomenon might be due to the fact that companies usually implement risk mitigation strategies to counteract the potential effects of *Demand Risks.* Moreover, *Production Process Risk* are manageable inside of a company, whereas *Demand Risks* are more difficult to handle. *Demand Risks* are the result of external factors, such as market trends and customer preferences, yet *Demand* forecast is an effective risk mitigation strategy.

- The relationship between *Supply Risks* and *Production Process Risk* reports a remarkably low value of β; moreover, its corresponding P value is visibly higher than 0.05. Such results imply that, according to the sample, perceived *Production Process Risk* are not the result of *Supply Risks* factors, but rather the result of internal activities, such as poor communication and system management.
- The impact of external risk factors, namely *Demand Risks* and *Supply Risks*, on *Production Process Risk* is hardly visible. It stands for merely 1% of the total variance of the dependent latent variable. In other words, internal risks depend on other factors.

11.3.2.6 Indirect Effects

Since Model D is relatively small, only one indirect effect was found. It occurs in the relationship between *Demand Risks* and *Production Process Risk.* Specifically, we found a two-segment indirect relationship between these variables through mediator variable *Supply Risks*. The magnitude of the effect is $\beta = 0.065$, yet $P = 0.083$. In other words, the relationship is not statistically significant. Such results indicate that perceived *Demand Risks* do not have any kind of effect on *Production Risk*, since the direct relationship was also not significant.

11.3.2.7 Total Effects

Even though the model does not report any significant indirect effects, both direct and in indirect effects must be considered to determine the total effects of a relationship, since the results might be significant. In this sense, Table 11.11 reports the results for the total effects estimated in the relationships between latent variables.

According to these results, it is possible to list the following interpretations:

- *Demand Risks* have a negative impact on *Supply Risks*, which is a source of external risks.
- External risk factors do not depend on internal risk factors, since they can be hardly managed inside of the organization.
- The total effects caused on *Demand Risks* are barely visible. This confirms the lack of interdependence among the variables.

Table 11.11 Total effects in complex Model D: *interrelations among supply chain risks variables*

To	From	
	Demand Risks	*Supply Risks*
Supply Risks	0.560 ($P < 0.001$)	
Production Process Risk	0.061 ($P = 0.085$)	0.109 ($P = 0.048$)

11.3.2.8 Final Conclusions of Complex Model D

Model D analyzes the interactions and interdependence among the three major supply chain risk factors. Furthermore, the model assumes the following order of risk factors: *Demand Risks* lead to *Supply Risks*, which in turn lead to *Production Process Risk*. The final conclusions regarding this model can be proposed as follows:

- *Demand Risks* and *Supply Risks* are external factors and independent from *Production Process Risk*. On the one hand, *Demand Risks* are associated with the supply process. On the other hand, *Supply Risks* are related to the flow of raw materials within the production system and depends more on the resources employed in the transformation processes.
- Manufacturing companies must invest enough time and money in external risk mitigation and management strategies and programs to be implemented in *Demand* forecast and supplier relationships.
- Internal risk management strategies must be implemented in the *Production Process Risk*. Internal risks can be more easily managed if compared to external risks. Nevertheless, organizations must find the appropriate balance between internal and external risk management. This balance can be reached through a joint collaboration among business partners, and it will allow every company involved to improve supply chain performance and increase both individual and collective competitiveness.

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Chapter 12
The Role of Regional Factors on Supply Chain Performance

12.1 Latent Variables

Since the goal of the book is to find the relationships between those variables affecting supply chain performance, this chapter analyzes two types of latent variables. The first type refers to regional elements, which can be listed as follows:

- *Regional Infrastructure*
- *Regional Costs*
- *Services*
- *Government*
- *Quality of Life*
- *Proximity*
- *Workforce*

As regards benefit variables, they can be thoroughly explored in the appendix section or in the methodology chapter. There are eight latent variables associated with supply chain performance. They can be listed below:

- *Delivery Times*
- *Quality*
- *Flexibility*
- *Customer Service*
- *Agility*
- *Financial Performance*
- *Inventory*
- *Transportation*

The following section introduces the simple models. Each one of these models associates one regional aspect with one supply chain performance benefit.

L. Avelar-Sosa et al., *Evaluation of Supply Chain Performance*,
Management and Industrial Engineering,
https://doi.org/10.1007/978-3-319-93876-9_12

12.2 Simple Models: Regional Factors—Supply Chain Performance (Benefits)

To provide a clearer and sounder understanding of the analyses that are conducted and discussed in this chapter, this section initially introduces two simple models, and then, some other more complex models are discussed. The simple models associate only two latent variables, whereas the complex models comprise three or more latent variables. The first simple model analyzes the relationship between *Regional Infrastructure and Agility*.

12.2.1 Simple Model A: Regional Infrastructure–Agility

This model proposes the interrelation between two latent variables: *Regional Infrastructure* and supply chain *Agility*, where it is hypothesized that the former has an impact on the latter. The goal of this model is to measure the impact of regional infrastructure elements, including land availability, power, railroad, transportation systems, and information and communication technologies (ICTs) on the ability of companies to rapidly respond to customer demands and product customization requirements. Figure 12.1 depicts the model proposed in this section.

12.2.1.1 Hypothesis Formulation: Simple Model A

The hypothesis proposed in Fig. 12.1 theorizes about the effects of regional infrastructure on supply chain agility in the countries where companies operate. Regional infrastructure refers to those technical structures that support society and economy; they include transportation, water supply, power distribution networks, flood control systems, and communication technologies (e.g., the Internet, radio, telephone) (Bhattacharyay 2009). Economically speaking, infrastructure can be considered as the structure that allows production and trade, of both products and services. In this sense, infrastructure is not limited to political-driven aspects, as it also encompasses ICTs, communication channels, software development, and social networks, among others, which give support to the economic system of a region or country.

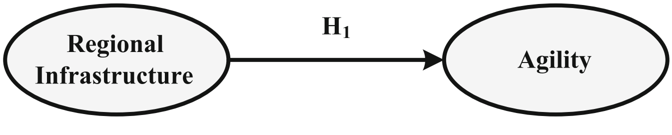

Fig. 12.1 Simple Model A proposed: *Regional Infrastructure–Agility*

On the other hand, agility refers to the strategic capacity of companies to rapidly detect and respond to internal and external uncertainties through efficient supply chain integration (Fayezi et al. 2017). Likewise, agility has been described as a company's ability to rapidly adapt and respond to changing customer needs (Gligor and Holcomb 2012), or as an organizational network within the supply chain that is integrated by materials, information, and financial flows that focus on ensuring supply chain flexibility (Costantino et al. 2012).

The relationship between infrastructure characteristics and supply chain agility has been empirically confirmed in the literature on supply chain agility and operations management. For instance, authors DeGroote and Marx (2013) proposed a structural equation model that relates information technologies (IT) (as the independent variable), agility, response to market changes (as mediator variables), and supply chain performance (as the result variable). Some IT aspects considered in this study included information sharing, transportation logistics, demand forecast, inventory management, product deliveries, and flexibility. In the end, the authors found that appropriate IT implementation improves supply chain agility.

From a different perspective, Yang (2014) proposed a structural equation model to validate the effects of IT, as an infrastructure element, on supply chain agility outcomes. The researchers concluded that communication is a key factor in vendor–buyer collaboration and communication improvement, which in turn provides benefits that can be transformed into economic growth. Here lies the importance of supply chain agility or adaptability. Finally, other studies have confirmed that infrastructure elements such as energy, transportation networks, and telecommunications have a significant impact on the growth of border cities (Barajas Bustillos and Gutiérrez Flores 2012). In this sense, the hypothesis of Model A can read as follows:

H_1. *Regional Infrastructure* has a positive direct effect on supply chain *Agility*.

12.2.1.2 Validation of Simple Model A and Conclusions

Before interpreting the model, the latent variables must be validated, as this would confirm the feasibility of the relationship in real life. The model proposed in Fig. 12.1 was tested, and its results are discussed in a new model, depicted in Fig. 12.2. As in previous models, the relationship is associated with a β value and a P value.

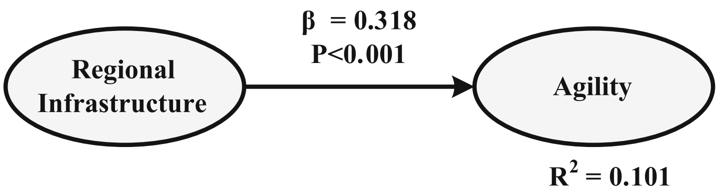

Fig. 12.2 Simple Model A evaluated: *Regional Infrastructure–Agility*

The former is a measure of dependency, whereas the latter indicates the statistical significance of the relationship. For a relationship to be considered as statistically significant, its corresponding *P* value must be lower than 0.05. Finally, R^2 in the dependent latent variable is a measure of explained variance.

Table 12.1 reports the validation results for this first model, which can be interpreted as follows:

- Latent variable *Agility* has enough parametric predictive validity, as both R^2 and Adjusted R^2 are higher than 0.02.
- Latent variable *Agility* has enough predictive validity from a nonparametric perspective, since Q^2 is higher than 0.02.
- The two latent variables have enough internal validity, since both the CAI and the composite reliability index have values higher than 0.7.
- The two latent variables have enough convergent validity, since AVE has values higher than 0.5.

Once the latent variables are validated, the model must be tested as a whole. To this end, ten model fit and quality indices are calculated as discussed in the methodology chapter:

- Average path coefficient (APC) = 0.318, $P < 0.001$
- Average *R*-Squared (R^2) (ARS) = 0.101, $P = 0.031$
- Average Adjusted *R*-Squared (AARS) = 0.097, $P = 0.035$
- Average block VIF (AVIF) not available
- Average Full collinearity VIF (AFVIF) = 1.089, acceptable if ≤ 5, ideally ≤ 3.3
- Tenenhaus GoF (GoF) = 0.350, small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36
- Simpson's Paradox Ratio (SPR) = 1.000, acceptable if ≥ 0.7, ideally = 1
- *R*-Squared Contribution Ratio (RSCR) = 1.000, acceptable if ≥ 0.9, ideally = 1
- Statistical Suppression Ratio (SSR) = 1.000, acceptable if ≥ 0.7
- Nonlinear Bivariate Causality Direction Ratio (NLBCDR) = 1.000, acceptable if ≥ 0.7

Table 12.1 Latent variable validation–simple Model A

Coefficient	Regional infrastructure	Agility
R-Squared (R^2)		0.101
Adjusted R^2		0.097
Composite reliability	0.842	0.909
Cronbach's alpha index (CAI)	0.749	0.874
Average variance extracted (AVE)	0.571	0.666
Full collinearity VIF	1.089	1.089
Q-Squared (Q^2)		0.102

According to these results, it is possible to infer the following conclusions:

- The relationship between *Regional Infrastructure* and *Agility* is statistically significant at a 95% confidence level, since the P value is lower than 0.05
- The model has appropriate adequate validity, since both ARS and AARS are higher than 0.02.
- The model is free from collinearity problems between the latent variables, since AFVIF is lower than 3.3.
- As indicated by the Tenenhaus GoF, the model has a good, but not high, fit to the data.
- The model is free from directionality problems related to the hypothesis.

12.2.1.3 Interpretation of Simple Model A

Once the model and its latent variables have been validated, we can proceed to their interpretation. In this sense, the research hypothesis has also been validated, as it is the relationship between the latent variables. The tested hypothesis can now read as follows:

H_1. There is enough statistical evidence to claim that *Regional Infrastructure* has a positive direct effect on supply chain *Agility* in the manufacturing industry, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.318 standard deviations. Such results imply that appropriate *Regional Infrastructure* allows the company to run better in the established region. In this sense, aspects such as efficient energy distribution channels and transportation and communication systems allow supply chain *Agility* to be improved through product lifecycles, delivery times, faster response to market change, and increased product customization capabilities. Likewise, since *Regional Infrastructure* can explain 10.1% of the variance of *Agility* (i.e., $R^2 = 0.101$), it is important that companies perform infrastructure needs assessments before deciding on a particular location.

To observe the behavior of the relationship between *Regional Infrastructure* and supply chain *Agility*, Fig. 12.3 shows the standardized values of the estimated parameters. The figure depicts a positive exponential curve, from which it is possible to conclude the following:

- If *Regional Infrastructure* is low, supply chain *Agility* levels will be low.
- The relationship between the latent variables stabilizes for a moment. When *Regional Infrastructure* shows values $1.5 - 0.3$, *Agility* levels are approximately -0.20. Then the value increases.
- This behavior demonstrates that *Regional Infrastructure* positively impacts on supply chain *Agility*.

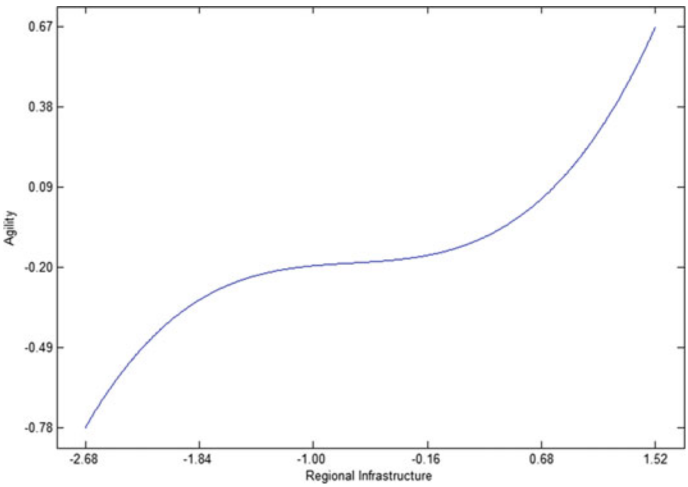

Fig. 12.3 Relationship of standardized values between *Regional Infrastructure–Agility*

12.2.2 Simple Model B: Workforce-Flexibility

This simple model proposes the relationship between two latent variables. On the one hand, *Workforce* is considered as the independent latent variables; on the other hand, *Flexibility* is viewed as the dependent latent variable. The goal of the model is to determine the impact of aspects such as employee availability, education levels, competency, skills, and abilities on the flexibility capabilities of companies. In this sense, flexibility allows companies to respond better and faster to customer needs and solve demand forecast problems. Figure 12.4 depicts the model proposed to be tested.

12.2.2.1 Hypothesis Formulation: Simple Model B

Agility and flexibility are very important aspects in supply chain environments. They allow companies to maximize benefits while improving cost management, customer service, and product quality. To be able to rapidly respond to customer needs, modern companies develop strategies that support and buffer the negative

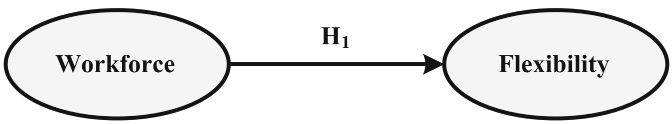

Fig. 12.4 Simple Model B proposed: *Workforce–Flexibility*

impact of market change. The results of these strategies are product variety, product quality, and delivery times met thanks to flexibility (Gómez-Cedeño et al. 2015).

Flexibility refers to the speed at which supply chain systems adapt and implement new strategies and production programs in order to support market change and product development (Garcia-Alcaraz et al. 2017). Supply chain flexibility involves flexibility in production processes, machinery, and tools. Human resources are a key aspect of supply chain flexibility. Their knowledge, abilities, attitudes, and skills determine to a great extent the adaptability of the supply chains.

Authors Kwon and Suh (2005) argue that employee commitment and trust are critical success factors for production, and therefore, they play an important role in supply chain performance, including flexibility (Alfalla-Luque et al. 2015). On the other hand, Mendes and Machado (2015) developed a structural equation model to study corporate performance. The authors conducted the research among 144 automotive manufacturing companies around the world and proved that employee skills encourage production flexibility, and thus, help face demand uncertainty problems. As main findings, the authors report that employees directly impact on flexibility, which in turn has a direct impact on organizational performance.

Employee skills and involvement have proved to positively influence on aspects such as financial performance and productivity (Kumari and Pradhan 2014), efficiency, and flexibility (Fu et al. 2013). Likewise, Lengnick-Hall et al. (2013) state that when collaborative work is encouraged, more benefits can be obtained, including competitiveness in terms of speed, agility, and flexibility. Furthermore, according to the authors, it is important to take advantage of employee knowledge and skills if companies want to become more flexible.

Employee participation along the whole supply chain system is one of the most important sources of added value. It encourages knowledge acquisition and application in each and thus improved corporate performance (He et al. 2013). In this sense, Yee et al. (2013) studied the relationships between workforce aspects (i.e., leadership, affective organizational commitment, goal-focused commitment, performance-centered organization, and service quality) and supply chain performance aspects, including flexibility. Studies have also emphasized on the impact of workforce knowledge on supply chain flexibility (Blome et al. 2014)

In their work, Garcia-Alcaraz et al. (2017) explored the effects of employee skills (e.g., education, knowledge, expertise) on supply chain performance in the wine industry. The authors found a positive direct relationship between the two variables and concluded that it is important for companies to employ engineers, managers, and operators who are competent enough in their field. This would allow supply chain systems to improve their performance.

Considering our discussion on the role of human resources in supply chain systems and our previous knowledge regarding employees as major decision makers, we propose the following research hypothesis:

H_1. Qualified *Workforce* has a positive direct effect on supply chain *Flexibility*.

12.2.2.2 Validation of Simple Model B and Conclusions

In structural equation modeling, latent variables must be validated before their relationships can be tested and then interpreted. The latent variables of this model were validated as discussed in the methodology section by estimating nine coefficients. The results of the validation process are introduced in Fig. 12.5 and Table 12.2.

According to the estimated coefficients, it is possible to conclude the following:

- Latent variable *Flexibility* has enough parametric predictive validity, since both R^2 and adjusted R^2 are higher than 0.02. Similarly, it has nonparametric predictive validity, since the value of Q^2 is also positive similar to the value of R^2.
- The two latent variables have enough internal validity, since the CAI and the composite reliability index are higher than 0.07, the minimum acceptable value.
- The two latent variables have enough convergent validity, since AVE is higher than 0.5.
- None of the latent variables has internal collinearity problems, since the values of VIF are lower than 3.3.

The two latent variables have proven to be reliable. Now, the model can be tested as a whole. In this sense, ten model fit and quality indices must be estimated as described in the methodology section. The results from this model validation process are listed below:

- Average Path Coefficient (APC) = 0.326, $P < 0.001$
- Average R-Squared (R^2) (ARS) = 0.106, $P = 0.027$

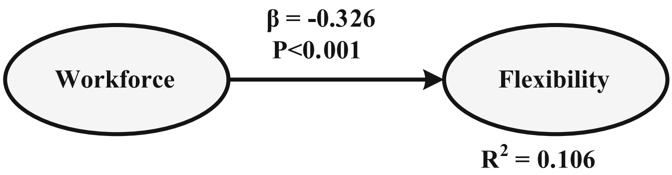

Fig. 12.5 Simple Model B evaluated: *Workforce–Flexibility*

Table 12.2 Latent variable validation–simple Model B

Coefficient	Workforce	Flexibility
R-Squared (R^2)		0.106
Adjusted R^2		0.102
Composite reliability	0.885	0.850
Cronbach's alpha index (CAI)	0.805	0.764
Average variance extracted (AVE)	0.720	0.589
Full collinearity VIF	1.071	1.071
Q-Squared (Q^2)		0.106

- Average Adjusted R-Squared (AARS) = 0.102, P = 0.030
- Average block VIF (AVIF) not available
- Average Full collinearity VIF (AFVIF) = 1.071, acceptable if ≤ 5, ideally ≤ 3.3
- Tenenhaus GoF (GoF) = 0.363, small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36
- Simpson's Paradox Ratio (SPR) = 1.000, acceptable if ≥ 0.7, ideally = 1
- R-Squared Contribution Ratio (RSCR) = 1.000, acceptable if ≥ 0.9, ideally = 1
- Statistical Suppression Ratio (SSR) = 1.000, acceptable if ≥ 0.7
- Nonlinear Bivariate Causality Direction Ratio (NLBCDR) = 1.000, acceptable if ≥ 0.7

According to these results, the following conclusions can be proposed for the relationship between *Workforce* and *Flexibility*:

- The relationship is statistically significant, since the P value of APC is higher than 0.5.
- Latent variable *Workforce* has enough predictive validity, since ARS and ARS are higher than 0.02, and their corresponding P values are lower than 0.05.
- The model is free from collinearity problems since AVIF is lower than 3.3. Notice that VIF cannot be estimated because the model only comprises two latent variables.
- The model has a good fit, according to the Tenenhaus GoF, whose value is equal to 0.36.
- The hypothesis does not show directionality problems.

12.2.2.3 Interpretation of Simple Model B

According to the estimated coefficients and model fit and quality indices, the model can be successfully interpreted. In other words, the model validates the feasibility of the relationship between *Workforce* and supply chain *Flexibility*. In this sense, the validated research hypothesis states as follows:

H_1. There is enough statistical evidence to claim that qualified *Workforce* has a positive direct effect on supply chain *Flexibility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.326 standard deviations. Such results indicate that companies must seek to settle in regions where human resources possess the skills, knowledge, and abilities that are necessary to efficiently run the company. Those regions should allow local engineers, managers, and operators to be easily located and hired. Workforce characteristics as regional aspects would allow organizations to significantly reduce time spent on deliveries and changeovers, among others. However, perhaps the major advantage of having qualified workforce is that it allows companies to better understand customer needs. Finally, Fig. 12.6 introduces a graph to depict the relationship between *Workforce* and supply chain *Flexibility*.

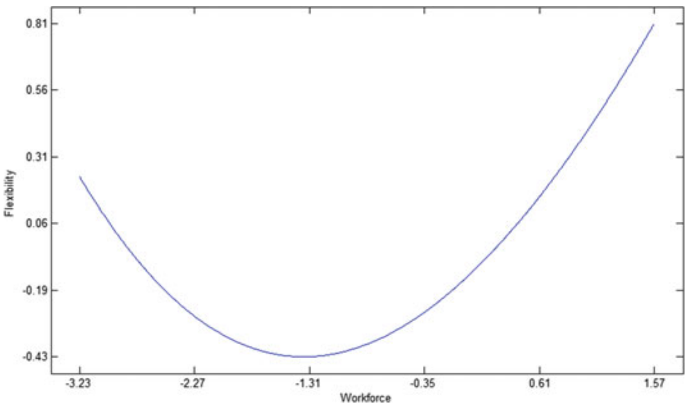

Fig. 12.6 Relationship of standardized values between *workforce* and *flexibility*

The graph allows us to provide the following interpretations:

- When human resources availability is insufficient, supply chain flexibility is high. This phenomenon might be due to the fact that manufacturing companies usually hire employees from other regions. In fact, a great number of employees hold special permits to work abroad.
- As human resources availability increases, companies rely more on local workforce. However, when such employees lack the necessary experience, supply chain flexibility levels decline to a minimum (see value −1.31 in *Workforce*).
- After this decline, the curve rises again. In other words, as *Workforce* availability increases, supply chain *Flexibility* increases as well. However, the curve does not remain stable at any point.

12.3 Summary of Simple Models: Regional Factors—Benefits

This chapter studies seven latent variables as regional factors. These factors are believed to have an impact on eight supply chain performance benefits, represented by eight dependent latent variables. In order to individually associate each regional factor with each one of the eight performance benefits, fifty-six simple models would be necessary. However, due to content-size restrictions and for concision purposes, we only provide graphic representations of two models (see Sect. 12.2), whereas the validation and interpretation processes for the remaining constructs will be summarized in this section.

12.3.1 *Latent Variable Validation for* Regional Factors

The first step in a model validation process involves validating the latent variables. Table 12.3 reports the coefficients estimated for the seven regional impact factors. Notice that coefficients R^2, adjusted R^2, and Q^2 are not estimated, since regional impact factors are considered to be independent latent variables and thus cannot be explained by other latent variables.

According to the results reported in Table 12.3, we can propose the following conclusions:

- All the latent variables representing regional impact factors have enough predictive validity, since the values of the CAI and the composite reliability index are higher than 0.07. Nevertheless, it is important to mention that item *Workforce costs make your operations competitive* was removed from latent variable *Regional Costs* to increase the reliability of the latent variable.
- All the latent variables have appropriate convergent validity, since AVE is higher than 0.5 in all the instances.

12.3.2 *Latent Variable Validation for* Supply Chain Performance (Benefits)

These latent variables were previously validated. The results of the validation process can be consulted in Table 12.4 and will thus be omitted in this chapter. As a reminder, all the benefit latent variables passed the three reliability tests performed on them:

- Internal validity, as measured by the CAI and the composite reliability index.
- Convergent validity, as measured by AVE.
- Internal collinearity, as measured by AVIF.

Table 12.3 Latent variable coefficients–*Regional Factors*

Coefficient	*A*	*B*	*C*	*D*	*E*	*F*	*G*
Composite reliability	0.842	0.838	0.941	0.919	0.884	0.807	0.885
Cronbach's alpha index (CAI)	0.749	0.739	0.874	0.889	0.824	0.740	0.805
Average variance extracted (AVE)	0.571	0.567	0.888	0.698	0.658	0.584	0.720

A regional infrastructure; *B* regional costs; *C* services; *D* government; *E* quality of Life; *F* proximity; *G* workforce

Table 12.4 Validation of hypotheses: *Regional factors–Benefits*

To	From						
	A	*B*	*C*	*D*	*E*	*F*	*G*
Delivery times	$\beta = 0.296$ ($P < 0.001$) $R^2 = 0.088$	$\beta = 0.279$ ($P < 0.001$) $R^2 = 0.078$	$\beta = 0.229$ ($P < 0.001$) $R^2 = 0.053$	$\beta = 0.278$ ($P < 0.001$) $R^2 = 0.077$	$\beta = 0.213$ ($P < 0.001$) $R^2 = 0.045$	$\beta = 0.280$ ($P < 0.001$) $R^2 = 0.078$	$\beta = 0.187$ ($P = 0.002$) $R^2 = 0.112$
Quality	$\beta = 0.248$ ($P < 0.001$) $R^2 = 0.061$	$\beta = 0.318$ ($P < 0.001$) $R^2 = 0.101$	$\beta = 0.166$ ($P = 0.006$) $R^2 = 0.027$	$\beta = 0.239$ ($P < 0.001$) $R^2 = 0.057$	$\beta = 0.186$ ($P = 0.002$) $R^2 = 0.035$	$\beta = 0.190$ ($P = 0.002$) $R^2 = 0.036$	$\beta = 0.218$ ($P < 0.001$) $R^2 = 0.058$
Flexibility	$\beta = 0.263$ ($P < 0.001$) $R^2 = 0.069$	$\beta = 0.253$ ($P < 0.001$) $R^2 = 0.064$	$\beta = 0.198$ ($P = 00.01$) $R^2 = 0.039$	$\beta = 0.256$ ($P < 0.001$) $R^2 = 0.066$	$\beta = 0.168$ ($P = 0.005$) $R^2 = 0.028$	$\beta = 0379$ ($P < 0.001$) $R^2 = 0.143$	$\beta = 0.326$ ($P < 0.001$) $R^2 = 0.087$
Customer service	$\beta = 0.249$ ($P < 0.001$) $\mathrm{R}^2 = 0.062$	$\beta = 0.331$ ($P < 0.001$) $R^2 = 0.109$	$\beta = 0.141$ ($P = 0.016$) $R^2 = 0.020$	$\beta = 0.316$ ($P < 0.001$) $R^2 = 0.100$	$\beta = 0.212$ ($P < 0.001$) $R^2 = 0.045$	$\beta = 0.341$ ($P < 0.001$) $R^2 = 0.116$	$\beta = 0.335$ ($P < 0.001$) $R^2 = 0.074$
Agility	$\beta = 0.318$ ($P < 0.001$) $R^2 = 0.101$	$\beta = 0.252$ ($P < 0.001$) $R^2 = 0.063$	$\beta = 0.246$ ($P < 0.001$) $R^2 = 0.061$	$\beta = 0.350$ ($P < 0.001$) $R^2 = 0.122$	$\beta = 0.214$ ($P < 0.001$) $R^2 = 0.046$	$\beta = 0.316$ ($P < 0.001$) $R^2 = 0.100$	$\beta = 0.273$ ($P < 0.001$) $R^2 = 0.112$
Financial performance	$\beta = 0.214$ ($P < 0.001$) $R^2 = 0.046$	$\beta = 0.241$ ($P < 0.001$) $R^2 = 0.058$	$\beta = 0.261$ ($P < 0.001$) $R^2 = 0.068$	$\beta = 0.272$ ($P < 0.001$) $R^2 = 0.074$	$\beta = 0.256$ ($P < 0.001$) $R^2 = 0.065$	$\beta = 0.214$ ($P < 0.001$) $R^2 = 0.046$	$\beta = 0.294$ ($P < 0.001$) $R^2 = 0.106$
Inventory	$\beta = 0.223$ ($P < 0.001$) $R^2 = 0.050$	$\beta = 0.304$ ($P < 0.001$) $R^2 = 0.092$	$\beta = 0.159$ ($P = 007$) $R^2 = 0.025$	$\beta = 0.304$ ($P < 0.001$) $R^2 = 0.093$	$\beta = 0.244$ ($P < 0.001$) $R^2 = 0.060$	$\beta = 0.291$ ($P < 0.001$) $R^2 = 0.085$	$\beta = 0.241$ ($P < 0.001$) $R^2 = 0.058$
Transportation	$\beta = 0.235$ ($P < 0.001$) $R^2 = 0.055$	$\beta = 0.173$ ($P = 0.004$) $R^2 = 0.030$	$\beta = 0.257$ ($P < 0.001$) $R^2 = 0.066$	$\beta = 0.338$ ($P < 0.001$) $R^2 = 0.114$	$\beta = 0.227$ ($P < 0.001$) $R^2 = 0.052$	$\beta = 0.298$ ($P < 0.001$) $R^2 = 0.089$	$\beta = 0.334$ ($P < 0.001$) $R^2 = 0.112$

A regional infrastructure; *B* regional costs; C services; *D* government; *E* quality of life; *F* proximity; *G* workforce

12.3.3 Simple Hypotheses: Regional Factors–Benefits

This subsection introduces the hypotheses that directly relate each regional impact factor with each supply chain performance benefit. Each one of the seven subsection below discusses the set of theorized relationships between one regional factors and the eight supply chain performance benefits.

12.3.3.1 Hypotheses: *Regional Infrastructure–Benefits*

Here is proposed eight hypotheses to associate regional infrastructure with the eight supply chain performance benefits.

H_1. In the manufacturing industry, *Regional Infrastructure* availability and accessibility have a positive direct impact on *Delivery Times*.

H_2. In the manufacturing industry, *Regional Infrastructure* availability and accessibility have a positive direct impact on production process *Quality*.

H_3. In the manufacturing industry, *Regional Infrastructure* availability and accessibility have a positive direct impact on production process *Flexibility*..

H_4. In the manufacturing industry, *Regional Infrastructure* availability and accessibility have a positive direct impact on *Customer Service*.

H_5. In the manufacturing industry, *Regional Infrastructure* availability and accessibility have a positive direct impact on *Agility*.

H_6. In the manufacturing industry, *Regional Infrastructure* availability and accessibility have a positive direct impact on *Financial Performance*.

H_7. In the manufacturing industry, *Regional Infrastructure* availability and accessibility have a positive direct impact on *Inventory* management performance.

H_8. In the manufacturing industry, *Regional Infrastructure* availability and accessibility have a positive direct impact on *Transportation* benefits.

12.3.3.2 Hypotheses: *Regional Costs–Benefits*

The second regional impact factor refers to those costs incurred by companies as a result of having access and using the infrastructure, human resources, and materials of the region where the company is established. The eight research hypotheses can read as follows:

H_1. In the manufacturing industry, moderate and adequate *Regional Costs* have a positive direct impact on *Delivery Times*.

H_2. In the manufacturing industry, moderate and adequate *Regional Costs* have a positive direct impact on production process *Quality*.

H_3. In the manufacturing industry, moderate and adequate *Regional Costs* have a positive direct impact on production process *Flexibility*.

H_4. In the manufacturing industry, moderate and adequate *Regional Costs* have a positive direct impact on *Customer Service*.

H_5. In the manufacturing industry, moderate and adequate *Regional Costs* have a positive direct impact on *Agility*.

H_6. In the manufacturing industry, moderate and adequate *Regional Costs* have a positive direct impact on *Financial Performance*.

H_7. In the manufacturing industry, moderate and adequate *Regional Costs* have a positive direct impact on *Inventory* management performance.

H_8. In the manufacturing industry, moderate and adequate *Regional Costs* have a positive direct impact on *Transportation* benefits.

12.3.3.3 Hypotheses: *Services–Benefits*

Companies need services in order to operate. Some of such services include ICTs, banking and financial services, and transportation. The availability and quality of these services surely has an impact on the performance of supply chain systems. This subsection discusses the relationships between the aforementioned services and the eight supply chain performance benefits.

H_1. In the manufacturing industry, *Services* availability and accessibility have a positive direct impact on *Delivery Times*.

H_2. In the manufacturing industry, *Services* availability and accessibility have a positive direct impact on production process *Quality*.

H_3. In the manufacturing industry, *Services* availability and accessibility have a positive direct impact on production process *Flexibility*.

H_4. In the manufacturing industry, *Services* availability and accessibility have a positive direct impact on *Customer Service*.

H_5. In the manufacturing industry, *Services* availability and accessibility have a positive direct impact on *Agility*.

H_6. In the manufacturing industry, *Services* availability and accessibility have a positive direct impact on *Financial Performance*.

H_7. In the manufacturing industry, *Services* availability and accessibility have a positive direct impact on *Inventory* management performance.

H_8. In the manufacturing industry, *Services* availability and accessibility have a positive direct impact on *Transportation* benefits.

12.3.3.4 Hypotheses: *Government–Benefits*

Through its three organizational levels—local, regional, national—the government sets the grounds for fair and legal trade. Among their major responsibilities toward companies, government institutions set operational procedures and establish legal inversion and tax policies. This section proposes eight research hypotheses to prove the impact of the *Government* on supply chain performance.

H_1. In the manufacturing industry, *Government* policies and functions have a positive direct impact on *Delivery Times*.

H_2. In the manufacturing industry, *Government* policies and functions have a positive direct impact on production process *Quality*.

H_3. In the manufacturing industry, *Government* policies and functions have a positive direct impact on production process *Flexibility*.

H_4. In the manufacturing industry, *Government* policies and functions have a positive direct impact on *Customer Service*.

H_5. In the manufacturing industry, *Government* policies and functions have a positive direct impact on *Agility*.

H_6. In the manufacturing industry, *Government* policies and functions have a positive direct impact on *Financial Performance*.

H_7. In the manufacturing industry, *Government* policies and functions have a positive direct impact on *Inventory* management performance.

H_8. In the manufacturing industry, *Government* policies and functions have a positive direct impact on *Transportation* benefits.

12.3.3.5 Hypotheses: *Quality of Life–Benefits*

The quality of life that a particular region offers determines the educational level of its people, the types of services available, and the social policies that dominate labor conditions (e.g., healthcare and social development policies). In this sense, the quality of life that a particular region has to offer has an impact on the performance of supply chain systems. To prove this assumption, the following eight research hypotheses are listed:

H_1. In the manufacturing industry, regional *Quality of Life* has a positive direct impact on *Delivery Times*.

H_2. In the manufacturing industry, regional *Quality of Life* has a positive direct impact on production process *Quality*.

H_3. In the manufacturing industry, regional *Quality of Life* has a positive direct impact on production process *Flexibility*.

H_4. In the manufacturing industry, regional *Quality of Life* has a positive direct impact on *Customer Service*.

H_5. In the manufacturing industry, regional *Quality of Life* has a positive direct impact on *Agility*.

H_6. In the manufacturing industry, regional *Quality of Life* has a positive direct impact on *Financial Performance*.

H_7. In the manufacturing industry, regional *Quality of Life* has a positive direct impact on *Inventory* management performance.

H_8. In the manufacturing industry, regional *Quality of Life* has a positive direct impact on *Transportation* benefits.

12.3.3.6 Hypotheses: *Proximity–Benefits*

Companies rely on a series of regional operational elements in order to operate successfully. Three of these elements are suppliers who provide raw materials, competitors that fuel innovation and leadership, and a market to sell its products and services. These elements are said to influence supply chain performance in various ways. Therefore, the following eight research hypotheses are proposed:

H_1. In the manufacturing industry, *Proximity* to suppliers, competitors, and buyers has a positive direct impact on *Delivery Times*.

H_2. In the manufacturing industry, *Proximity* (in terms of suppliers, competitors, and buyers) has a positive direct impact on production process *Quality*.

H_3. In the manufacturing industry, *Proximity* to suppliers, competitors, and buyers has a positive direct impact on production process *Flexibility*.

H_4. In the manufacturing industry, *Proximity* to suppliers, competitors, and buyers has a positive direct impact on *Customer Service*.

H_5. In the manufacturing industry, *Proximity* to suppliers, competitors, and buyers has a positive direct impact on *Agility*.

H_6. In the manufacturing industry, *Proximity* to suppliers, competitors, and buyers has a positive direct impact on *Financial Performance*.

H_7. In the manufacturing industry, *Proximity* to suppliers, competitors, and buyers has a positive direct impact on *Inventory* management performance.

H_8. In the manufacturing industry, *Proximity* to suppliers, competitors, and buyers has a positive direct impact on *Transportation* benefits.

12.3.3.7 Hypotheses: *Workforce-Benefits*

Human resources are another important regional impact factor. The education and availability of employees indicate how much training must be provided. In fact, the presence or absence of a qualified workforce usually determines the location of a business, yet companies are also required to develop and implement effective employee retention strategies. From this perspective, a qualified workforce undoubtedly has an impact on supply chain performance benefits. That said, to quantify this relationship, the eight research hypotheses state as follows:

H_1. In the manufacturing industry, *Workforce* availability, education, and skills have a positive direct impact on *Delivery Times*.

H_2. In the manufacturing industry, *Workforce* availability, education, and skills have a positive direct impact on production process *Quality*.

H_3. In the manufacturing industry, *Workforce* availability, education, and skills have a positive direct impact on production process *Flexibility*.

H_4. In the manufacturing industry, *Workforce* availability, education, and skills have a positive direct impact on *Customer Service*.

H_5. In the manufacturing industry, *Workforce* availability, education, and skills have a positive direct impact on *Agility*.

H_6. In the manufacturing industry, *Workforce* availability, education, and skills have a positive direct impact on *Financial Performance*.

H_7. In the manufacturing industry, *Workforce* availability, education, and skills have a positive direct impact on *Inventory* management performance.

H_8. In the manufacturing industry, *Workforce* availability, education, and skills have a positive direct impact on *Transportation* benefits.

12.4 Validation of Simple Hypotheses: Regional Factors—Benefits

Since two of the aforementioned hypotheses were modeled in the beginning of the chapter, this section discusses and interprets the validation results from the remaining 54 relationships. As Table 12.4 reports, every validated relationship includes three parameters: β is a measure of dependency, P indicates the statistical significance of the relationship, and R^2 measures the percentage of variance in the dependent latent variable that is explained by the independent latent variable. As a reminder, significant relationships have a P value lower than 0.05. Finally, regional impact factors are placed in the first row of the table, while supply chain performance benefits are listed in the first column.

12.5 Conclusions on Simple Hypotheses: Regional Factors—Benefits

This section interprets the results reported in Table 12.4 with respect to the research hypotheses proposed in Sect. 12.4. Those relationships that have a P value lower than 0.05 are statistically significant at a 95% confidence level, whereas those with a P value higher than the threshold are not significant. As in Sect. 12.4, conclusions are provided for each regional impact factor.

12.5.1 Validation of Hypotheses: Regional Infrastructure—Benefits

This subsection discusses the eight validated relationships between regional infrastructure and supply chain performance benefits in the manufacturing industry. Such results are summarized in column A of Table 12.4.

H_1. In the manufacturing industry, there is enough statistical evidence to claim that *Regional Infrastructure* has a positive direct impact on *Delivery Times*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.296 standard deviations.

H_2. In the manufacturing industry, there is enough statistical evidence to claim that *Regional Infrastructure* has a positive direct impact on production process *Quality*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.248 standard deviations.

H_3. In the manufacturing industry, there is enough statistical evidence to claim that *Regional Infrastructure* has a positive direct impact on production process *Flexibility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.263 standard deviations.

H_4. In the manufacturing industry, there is enough statistical evidence to claim that *Regional Infrastructure* has a positive direct impact on *Customer Service*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.249 standard deviations.

H_5. In the manufacturing industry, there is enough statistical evidence to claim that *Regional Infrastructure* has a positive direct impact on *Agility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.318 standard deviations.

H_6. In the manufacturing industry, there is enough statistical evidence to claim that *Regional Infrastructure* has a positive direct impact on *Financial Performance*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.214 standard deviations.

H_7. In the manufacturing industry, there is enough statistical evidence to claim that *Regional Infrastructure* has a positive direct impact on *Inventory* management performance, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.223 standard deviations.

H_8. In the manufacturing industry, there is enough statistical evidence to claim that *Regional Infrastructure* has a positive direct impact on *Transportation* benefits, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.235 standard deviations.

12.5.2 Conclusions and Implications of Hypotheses: Regional Infrastructure—Benefits

According to the results summarized in Table 12.4, column A, we can propose the following conclusions on the relationships between regional infrastructure and supply chain performance benefits:

- *Regional Infrastructure* has the largest impact on *Agility*, thereby implying that it allows companies to ensure a rapid response to customer needs. The value of β in this relationship is equal to 0.318, whereas $R^2 = 0.10$.
- ICTs are a part of *Regional Infrastructure* that streamlines decision-making processes. This in turn makes companies more agile.

- The impact of *Regional Infrastructure* on *Delivery Times* is $\beta = 0.296$, indicating that better access to infrastructure allows companies to deliver their products on time and thus maintain their reputation.
- *Regional Infrastructure* has the smallest impact on *Financial Performance*, being $\beta = 0.214$. The value of this relationship is due to the fact that infrastructure services must be paid and consume resources. This conclusion would also explain the value of $R^2 = 0.046$.

12.5.3 *Validation of Hypotheses:* Regional Costs—Benefits

This subsection discusses the hypotheses between costs and supply chain performance benefits after their validation (see Table 12.4, column B). As a reminder, costs in this chapter refer to those expenses incurred in infrastructure services and human resource employment.

H_1. In the manufacturing industry, there is enough statistical evidence to claim that moderate and appropriate *Regional Costs* have a positive direct impact on *Delivery Times*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.279 standard deviations.

H_2. In the manufacturing industry, there is enough statistical evidence to claim that moderate and appropriate *Regional Costs* have a positive direct impact on production process *Quality*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.318 standard deviations.

H_3. In the manufacturing industry, there is enough statistical evidence to claim that moderate and appropriate *Regional Costs* have a positive direct impact on production process *Flexibility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.253 standard deviations.

H_4. In the manufacturing industry, there is enough statistical evidence to claim that moderate and appropriate *Regional Costs* have a positive direct impact on *Customer Service*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.331 standard deviations.

H_5. In the manufacturing industry, there is enough statistical evidence to claim that moderate and appropriate *Regional Costs* have a positive direct impact on *Agility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.252 standard deviations.

H_6. In the manufacturing industry, there is enough statistical evidence to claim that moderate and appropriate *Regional Costs* have a positive direct impact on *Financial Performance*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.241 standard deviations.

H_7. In the manufacturing industry, there is enough statistical evidence to claim that moderate and appropriate *Regional Costs* have a positive direct impact on

Inventory management performance, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.304 standard deviations.

H_8. In the manufacturing industry, there is enough statistical evidence to claim that moderate and appropriate *Regional Costs* have a positive direct impact on *Transportation* benefits, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.173 standard deviations.

12.5.4 Conclusions and Implications of Hypotheses: Regional Costs—Benefits

Following our previous discussion on the validated hypotheses, it is possible to provide the following conclusions:

- All the effects are statistically significant and positive.
- All the dependent latent variables have enough predictive validity, since all the values of R^2 are higher than 0.02.
- *Regional Costs* incurred in infrastructure and human resources have the largest impact on *Customer Service*, being $\beta = 0.331$. In other words, both employee salaries and infrastructure services, which are to be paid, allow companies to deliver their products on time. Such implications are consistent with the value of R^2, which is equal to 0.109.
- *Regional Costs* incurred in infrastructure and human resources have the second largest impact on production process *Quality*. Such results might be due to the technology systems and tools that companies can afford as well as the qualified workforce it can employ. Finally, this relationship has $R^2 = 0.101$.
- The relationship between *Regional Costs* and *Transportation* benefits is low, being $\beta = 0.173$ and $R^2 = 0.030$. Such results indicate that although companies can rely on the necessary infrastructure and transportation services, *Regional Costs* are high.

12.5.5 Validation of Hypotheses: Services—Benefits

The eight validated hypotheses between services and supply chain performance benefits can be summarized below:

H_1. In the manufacturing industry, there is enough statistical evidence to claim that regional *Services* have a positive direct impact on *Delivery Times*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.229 standard deviations.

H_2. In the manufacturing industry, there is enough statistical evidence to claim that regional *Services* have a positive direct impact on production process *Quality*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.166 standard deviations.

H_3. In the manufacturing industry, there is enough statistical evidence to claim that regional *Services* have a positive direct impact on production process *Flexibility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.198 standard deviations.

H_4. In the manufacturing industry, there is enough statistical evidence to claim that regional *Services* have a positive direct impact on *Customer Service*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.141 standard deviations.

H_5. In the manufacturing industry, there is enough statistical evidence to claim that regional *Services* have a positive direct impact on *Agility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.246 standard deviations.

H_6. In the manufacturing industry, there is enough statistical evidence to claim that regional *Services* have a positive direct impact on *Financial Performance*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.261 standard deviations.

H_7. In the manufacturing industry, there is enough statistical evidence to claim that regional *Services* have a positive direct impact on *Inventory* management performance, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.159 standard deviations.

H_8. In the manufacturing industry, there is enough statistical evidence to claim that regional *Services* have a positive direct impact on *Transportation* benefits, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.257 standard deviations.

12.5.6 Conclusions and Implications of Hypotheses: **Services—Benefits**

According to our discussion on the effects of regional services on supply chain performance benefits, and as inferred from Table 12.4, column C, the following conclusions can be provided:

- All the effects of regional *Services* on supply chain performance benefits are statistically positive and significant.
- All the dependent latent variables have enough predictive validity, since all the values of R^2 are higher than 0.02.
- Regional *Services* have the largest impacts on *Financial Performance* and *Transportation* benefits. Such results indicate that services such as banks, schools, airports, and high roads facilitate economic development and allow

companies to meet delivery deadlines. This conclusion is supported by the high explanatory value of R^2 in all the dependent latent variables.

- The relationship between regional *Services* and *Customer Service* has the smallest impact, thereby implying that services availability cannot always guarantee on-time product deliveries. This conclusion is consistent with the low explanatory power value of R^2.

12.5.7 Validation of Hypotheses: Government—Benefits

The government is one of the most important institutions for business and corporate development. According to the results summarized in Table 12.4, column D, it is possible to provide the following conclusions with respect to the relationships between government and supply chain performance benefits:

H_1. In the manufacturing industry, there is enough statistical evidence to claim that *Government* policies and management have a positive direct impact on *Delivery Times*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.278 standard deviations.

H_2. In the manufacturing industry, there is enough statistical evidence to claim that *Government* policies and management have a positive direct impact on production process *Quality*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.239 standard deviations.

H_3. In the manufacturing industry, there is enough statistical evidence to claim that *Government* policies and management have a positive direct impact on production process *Flexibility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.256 standard deviations.

H_4. In the manufacturing industry, there is enough statistical evidence to claim that *Government* policies and management have a positive direct impact on *Customer Service*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.316 standard deviations.

H_5. In the manufacturing industry, there is enough statistical evidence to claim that *Government* policies and management have a positive direct impact on *Agility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.350 standard deviations.

H_6. In the manufacturing industry, there is enough statistical evidence to claim that *Government* policies and management have a positive direct impact on *Financial Performance*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.272 standard deviations.

H_7. In the manufacturing industry, there is enough statistical evidence to claim that *Government* policies and management have a positive direct impact on *Inventory* management performance, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.304 standard deviations.

H_8. In the manufacturing industry, there is enough statistical evidence to claim that *Government* policies and management have a positive direct impact on *Transportation* benefits, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.338 standard deviations.

12.5.8 Conclusions and Implications of Hypotheses: Government—Benefits

The relationships between government actions and supply chain performance benefits were interpreted in our previous discussion. In this section, we propose a series of conclusions and implications with respect to these relationships.

- All the relationships are statistically significant and positive. Such results indicate that the *Government* is an element vital for supply chain performance. Similarly, all the dependent latent variables have enough predictive validity, since their corresponding R^2 values are higher than 0.02, the minimum acceptable value.
- *Government* has the largest impact on *Agility*, being $\beta = 0.350$. In other words, government institutions, and thus policies and actions, help companies better respond to customer needs, reduce cycle times, and improve product customization. This might be due to the fact that the government facilitates the operational management of the companies. In this sense, the value of R^2 is equal to 0.122.
- The relationship between the *Government* and *Transportation* benefits is also high ($\beta = 0.338$ and $R^2 = 0.114$). Such results imply that high roads and transportation systems provided by the government as public services allow companies to operate successfully.
- Conversely, the relationship between the *Government* and production process *Quality* reports the lowest value. The low magnitude of this relationship might be due to the fact that quality in the production process is more an internal benefit, rather than a benefit provided by external factors.

12.5.9 Validation of Hypotheses: Quality of Life—Benefits

The results summarized in Table 12.4, column E, as regards the validated relationships between regional qualify of life and performance benefits in supply chain systems can be interpreted as follows:

H_1. In the manufacturing industry, there is enough statistical evidence to claim that regional *Quality of Life* has a positive direct impact on *Delivery Times*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.213 standard deviations.

H_2. In the manufacturing industry, there is enough statistical evidence to claim that regional *Quality of Life* has a positive direct impact on production process *Quality*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.186 standard deviations.

H_3. In the manufacturing industry, there is enough statistical evidence to claim that regional *Quality of Life* has a positive direct impact on production process *Flexibility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.168 standard deviations.

H_4. In the manufacturing industry, there is enough statistical evidence to claim that regional *Quality of Life* has a positive direct impact on *Customer Service*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.212 standard deviations.

H_5. In the manufacturing industry, there is enough statistical evidence to claim that regional *Quality of Life* has a positive direct impact on *Agility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.214 standard deviations.

H_6. In the manufacturing industry, there is enough statistical evidence to claim that regional *Quality of Life* has a positive direct impact on *Financial Performance*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.256 standard deviations.

H_7. In the manufacturing industry, there is enough statistical evidence to claim that regional *Quality of Life* has a positive direct impact on *Inventory* management performance, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.244 standard deviations.

H_8. In the manufacturing industry, there is enough statistical evidence to claim that regional *Quality of Life* has a positive direct impact on *Transportation* benefits, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.227 standard deviations.

12.5.10 *Conclusions and Implications of Hypotheses:* Quality of Life—Benefits

The relationships found between regional quality of life and supply chain performance benefits have important implications for the manufacturing industry. Such implications are listed below:

- Regional *Quality of Life* has a positive direct impact on the eight supply chain performance benefits discussed in this book. Such results indicate that the quality of life that a particular geographical region has to offer can either boost or compromise the performance of supply chain systems. Moreover, as demonstrated by all the values of R^2 (all of them higher than 0.02), *Quality of Life* has a large explanatory power in all the relationships.

- Regional *Quality of Life* has the largest impact on *Financial Performance*, being $\beta = 0.256$. In other words, the quality of life of people is reflected on their purchasing power. However, the explanatory power in this relationship is not as high as in other relationships, since $R^2 = 0.06$.
- The relationship between *Quality of Life* and production process *Flexibility* is also important but significantly smaller in magnitude. The value of β is only 0.168, whereas the first latent variable can only explain 2.8% of the variance of the second latent variable. Such results might be due to the fact that quality of life is rather an external factor, and companies have little control on it.

12.5.11 *Validation of Hypotheses:* Proximity—Benefits

Companies need to take into account a series of operational aspects in order to survive in a particular region. Some of these aspects are proximity to raw materials and the market, the location of competitors, and market opportunities. In this sense, this section discusses the results reported in Table 12.4, column F, regarding the validation of the relationships between *Proximity* and supply chain performance benefits:

H_1. In the manufacturing industry, there is enough statistical evidence to claim that *Proximity* to suppliers, competitors, and buyers has a positive direct impact on *Delivery Times*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.280 standard deviations.

H_2. In the manufacturing industry, there is enough statistical evidence to claim that *Proximity* to suppliers, competitors, and buyers has a positive direct impact on production process *Quality*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.190 standard deviations.

H_3. In the manufacturing industry, there is enough statistical evidence to claim that *Proximity* to suppliers, competitors, and buyers has a positive direct impact on production process *Flexibility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.379 standard deviations.

H_4. In the manufacturing industry, there is enough statistical evidence to claim that *Proximity* to suppliers, competitors, and buyers has a positive direct impact on *Customer Service*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.341 standard deviations.

H_5. In the manufacturing industry, there is enough statistical evidence to claim that *Proximity* to suppliers, competitors, and buyers has a positive direct impact on *Agility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.316 standard deviations.

H_6. In the manufacturing industry, there is enough statistical evidence to claim that *Proximity* to suppliers, competitors, and buyers has a positive direct impact on *Financial Performance*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.214 standard deviations.

H_7. In the manufacturing industry, there is enough statistical evidence to claim that *Proximity* to suppliers, competitors, and buyers has a positive direct impact on *Inventory* management performance, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.291 standard deviations.

H_8. In the manufacturing industry, there is enough statistical evidence to claim that *Proximity* to suppliers, competitors, and buyers has a positive direct impact on *Transportation* benefits, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.298 standard deviations.

12.5.12 *Conclusions and Implications:* Proximity—Benefits

According to the interpretations on the results summarized in Table 12.4, column F, it is possible to provide the following conclusions on the relationships between *Proximity* and supply chain performance benefits.

- As indicated by the values of β, *Proximity* to suppliers and customers has a positive direct impact on supply chain performance benefits. Moreover, the variance of the dependent latent demonstrates that the relationships have enough predictive validity.
- *Proximity* has the largest direct impact on production process *Flexibility*. In fact, being close to both customers and suppliers allows organizations to respond better to unexpected market and demand changes. Likewise, according to the R^2 coefficient, *Proximity* can explain up to 14.3% of the variance of production process *Flexibility*, since R^2 = de 0.143.
- The relationships between *Proximity* and both *Customer Service* and *Agility* are similarly relevant due to the β coefficient ($\beta = 0.34$ and $\beta = 10.316$, respectively). Such results indicate that proximity to customers and suppliers allow companies to meet specific customer needs thank to the close physical relationship between them.
- *Proximity* has the lowest direct effect on production process *Quality*, as measured by the β coefficient ($\beta = 0.190$). This might be due to the fact that quality in the production process is generated inside the company, not by external factors.

12.5.13 Validation of Hypotheses: Workforce–Benefits

Workforce is another important factor for supply chain performance. Since c employees make it possible for the raw materials to be transported and the final products to be delivered, organizations without a skilled and experienced workforce will not be able to reach performance goals successfully. This subsection interprets the results of the validated relationships between regional *Workforce* and supply chain performance benefits, previously reported in Table 12.4, column G.

H_1. In the manufacturing industry, there is enough statistical evidence to claim that regional *Workforce* has a positive direct impact on *Delivery Times*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.187 standard deviations.

H_2. In the manufacturing industry, there is enough statistical evidence to claim that regional *Workforce* has a positive direct impact on production process *Quality*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.218 standard deviations.

H_3. In the manufacturing industry, there is enough statistical evidence to claim that regional *Workforce* has a positive direct impact on production process *Flexibility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.326 standard deviations.

H_4. In the manufacturing industry, there is enough statistical evidence to claim that regional *Workforce* has a positive direct impact on *Customer Service*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.355 standard deviations.

H_5. In the manufacturing industry, there is enough statistical evidence to claim that regional *Workforce* has a positive direct impact on *Agility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.273 standard deviations.

H_6. In the manufacturing industry, there is enough statistical evidence to claim that regional *Workforce* has a positive direct impact on *Financial Performance*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.294 standard deviations.

H_7. In the manufacturing industry, there is enough statistical evidence to claim that regional *Workforce* has a positive direct impact on *Inventory* management performance, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.241 standard deviations.

H_8. In the manufacturing industry, there is enough statistical evidence to claim that regional *Workforce* has a positive direct impact on *Transportation* benefits, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.334 standard deviations.

12.5.14 Conclusions and Implications of Hypotheses: Workforce–Benefits

According to the hypothesis validation results reported in Table 12.4, column G, and interpreted in the previous section, we can discuss the following conclusions with respect to the impact of regional *Workforce* on supply chain performance benefits:

- *Workforce* is one of the most important regional elements for supply chain performance. All its relationships with supply chain performance benefits are statistically significant and positive since the *P* values are lower than 0.05. Similarly, all the dependent latent variables have enough explanatory power, since the R^2 coefficient is always higher than 0.02, the minimum acceptable value.
- *Workforce* has the largest direct impacts on both *Customer Service* and production process *Flexibility* ($\beta = 0.335$ and $\beta = 0.326$, respectively) thereby implying that qualified, skilled, and multidisciplinary employees help companies reduce changeover times and improve customer needs fulfillment. However, if compared to other regional impact factors, *Workforce* has a lower explanatory power over supply chain performance benefits.
- The relationship between *Workforce* and *Delivery Times* has the smallest effect value ($\beta = 0.187$) but the highest explanatory power value ($R^2 = 0.112$). Such results imply that *Workforce* is vital for timely and complete product deliveries.

12.6 Complex Models: Interrelations Among Regional Factors

Sections 12.2.1 and 12.2.2 analyze two simple models that relate one regional factor to one supply chain performance benefit each. Then, we provided a summary of the 56 possible simple models (see Sect. 12.5), whose validation results were reported in Table 12.4. To provide a more comprehensive analysis, this section explores the interrelations among regional factors; that is, we explore which regional factors are the most important to be considered, which ones are interrelated and how strong this interrelation is.

12.6.1 Complex Model C: Regional Factors

The model assumes that latent variable *Government* is the main driver, since it provides existent *Regional Infrastructure*, such as high roads and airports, and sets regulations for services, costs, and prices. Figure 12.7 depicts the model initially

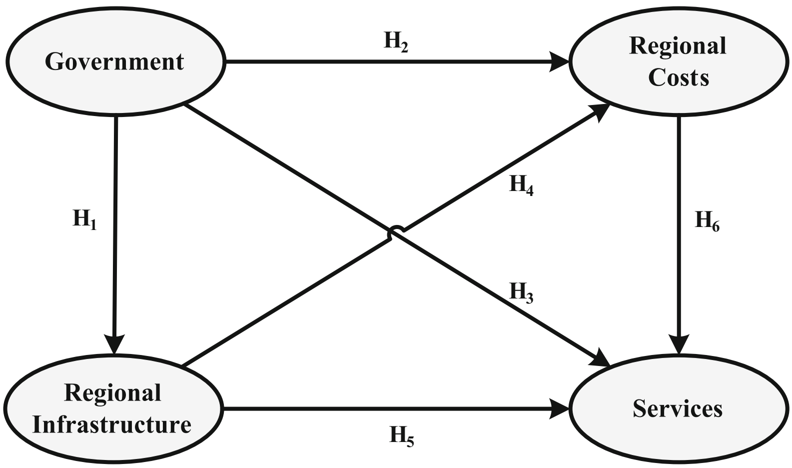

Fig. 12.7 Complex Model C proposed: *Regional Factors*

proposed, where *Government* is located in the top-left corner since it is believed to have an impact on the remaining latent variables. In turn, *Services* is considered to be the response variable and is believed to depend on both *Regional Infrastructure* and *Regional Costs*. Therefore, the model allows six research hypotheses to be proposed and tested. The complex model developed in this section comprises four latent variables:

- *Government*
- *Regional Infrastructure*
- *Regional Costs*
- *Services*

12.6.1.1 Hypotheses Formulation: Complex Model C

Several research works support the proposal of Model C. Studies on supply chain performance claim that active government involvement is essential for return on investments. Government institutions find in the private sector the necessary experience and speed to boost its infrastructure and services availability, and consequently, to increase international competitiveness.

The role of the *Government* is key to handling critical situations, environmental crises, and infrastructure utilization and optimization. Furthermore, it influences supply chain performance through incentive programs, market policies, and resource utilization policies. Every government action and support affect the quality of the products and services that companies offer (Mahmoudi and Rasti-Barzoki 2018).

Aspects of national infrastructure include education systems, consulting agencies, and corporate infrastructure, such as engineers, managers, laboratories, knowledge, and abilities, among others (Moljevic 2016). All these aspects encourage economic development in companies, and consequently, in countries. The most common local infrastructure services include municipal roads, street paving, streetlighting, water supply, sewer systems, and health care (Lall et al. 2010). The role of transportation systems in economic growth depends on the quantity and quality of the existent infrastructure (Deng et al. 2014). Similarly, port infrastructure has a positive impact on regional economic growth. The influence of port infrastructure does not only depend on its availability; it is also affected by its use and exploitation.

As Doh and Kim (2014) claim, each government has its own initiatives and policies to encourage innovation across small and medium-sized enterprises (SMEs). Government actions seek to improve access to financing and information infrastructures while simultaneously providing legal and financial regulatory frameworks. Export-oriented manufacturing companies with such initiatives manage to expand and improve their economic stability. Therefore, port infrastructure must be linked to public projects and policies that encourage the use, exploitation, and social benefits of regional infrastructure (Zepeda-Ortega et al. 2017). In this sense, the first research hypothesis of the model can read as follows:

H_1. In the manufacturing industry, *Government* support and management have a positive direct impact on *Regional Infrastructure*.

According to Bhatnagar and Sohal (2005), public policies affect both infrastructure and service costs. In their research, the authors conducted a linear regression analysis and found a strong relationship between regional aspects and corporate competitiveness. In this sense, infrastructure services and elements must serve productive development and must be planned in such a way that they support current and future production centers. Likewise, national infrastructure policies must be conceived as a continuous improvement process that must be revised and modified if necessary to be able to respond successfully to internal and external environments (Cipoletta et al. 2010). Moreover, service and infrastructure policies must be designed, planned, and regulated under frameworks that guide and relate key aspects for development, production, infrastructure, transportation, and logistics and mobility services (Jaimurzina et al. 2016). Finally, land *Costs* are another important impact factor (Nguyen and Sano 2010). Therefore, the second research hypotheses of model C can be proposed below:

H_2. In the manufacturing industry, *Government* support and management have a positive direct impact on *Regional Infrastructure* and service *Costs*.

The *Government* is also a decisive factor in infrastructure- and transportation-related investments. *Government* support is necessary for productive development, especially in terms of international trade, where ports and navigable routes (Blyde and Molina 2015). In this sense, there must be a positive correspondence between transportation infrastructure (by both land and sea) and productivity growth (Sánchez et al. 2017). Therefore, the third research hypotheses can be proposed below:

H_3. In the manufacturing industry, *Government* support and management have a positive direct impact on the availability of regional *Services*.

Regional Costs incurred in *Regional Infrastructure* and human resources employment must be taken into account when determining operational and financial dimensions in supply chain systems (Mohammadi et al. 2017). Such dimensions can be mathematically modeled in order to support and improve both decision-making and supply chain performance. According to Kwon et al. (2016), financial performance improvement in supply chain systems requires the planning and implementation of efficient quality improvement and cost reduction strategies. Likewise, Sánchez and Gómez Paz (2017) claim that low-cost *Regional Infrastructure*, shorter operational times, and more reliable services depend not only on the physical *Infrastructure* of that region, but also on those market conditions that are determined by transportation policies and their economic regulations. Under such premises, it is possible to develop the fourth research hypotheses as follows:

H_4. In the manufacturing industry, *Regional Infrastructure* has a positive direct impact on infrastructure and service *Costs*.

Quality in *Regional Infrastructure*, such as in transportation routes, provides opportunities for companies to interact with customers. Enterprises that are established in regions with good infrastructure are more integrated into the market system and thus have more competitors. Consequently, they might be under higher pressure, but this will boost their productivity (Deishmann et al. 2004). When *Infrastructure* services have the potential to improve the accessibility of a region, they can also positively impact on other regions. Moreover, resources such as capital and workforce will allow for new and more attractive infrastructure to be built (Tselios et al. 2017). *Services* and their availability in manufacturing supply chain systems are a key for customer satisfaction. Public development policies aim at ensuring adequate infrastructure and efficient logistic *Services* to contribute to better productivity and provide competitive advantages (Sánchez and Gómez Paz 2017). In conclusion, *Regional Infrastructure* elements, such as land and availability, transportation energy services, and telecommunication services improve the logistic *Services* that are necessary for companies to operate successfully. Therefore, the fifth working hypothesis of this research is read as follows:

H_5. In the manufacturing industry, *Regional Infrastructure* has a positive direct effect on *Services* availability and quality.

To Alayet et al. (2018), costs derived from an appropriate planning of human resources, transportation, storage, and production increase competitiveness while simultaneously reducing logistic costs along the whole supply chain. In their work, Aljazzar et al. (2018) discuss a novel suggestion for supply chain performance optimization by developing a model of input costs, carbon emission costs (from manufacturing and transportation), purchase costs, and supply chain coordination *Costs*. The model was run under multiple scenarios and sought to find delivery time rates improvement. On the other hand, Sánchez (2004) argue that infrastructure investments have an impact on service costs minimization (e.g., land, sea, and river transportation costs) (Sánchez and Gómez Paz 2017) and simultaneously increase land connectivity and accessibility. Similarly, low services costs incentivize direct foreign investment and thus promote economic development. The final research hypotheses derived from this discussion is proposed below:

H_6. In the manufacturing industry, the level of competitiveness of *Regional Costs* has a positive direct effect on *Services* availability and quality.

12.6.1.2 Results of Complex Model C: *Regional Factors*

The results of the model evaluation process are depicted in Fig. 12.8. Each relationship between two latent variables is associated with three coefficients. The β coefficient is a measure of dependency, whereas R^2 indicates the amount of variance in a dependent latent variable that is explained by independent latent variables. Finally, the P value indicates the statistical significance of the relationship. P values lower than 0.05 point at statistically significant relationships.

According to the results reported in the figure, we can propose the following conclusions as regards the validity of the relationships:

- All the relationships are statistically significant because all the P values are lower than 0.05.
- All the dependent latent variables have enough predictive validity, since all the values of R^2 are higher than 0.02.

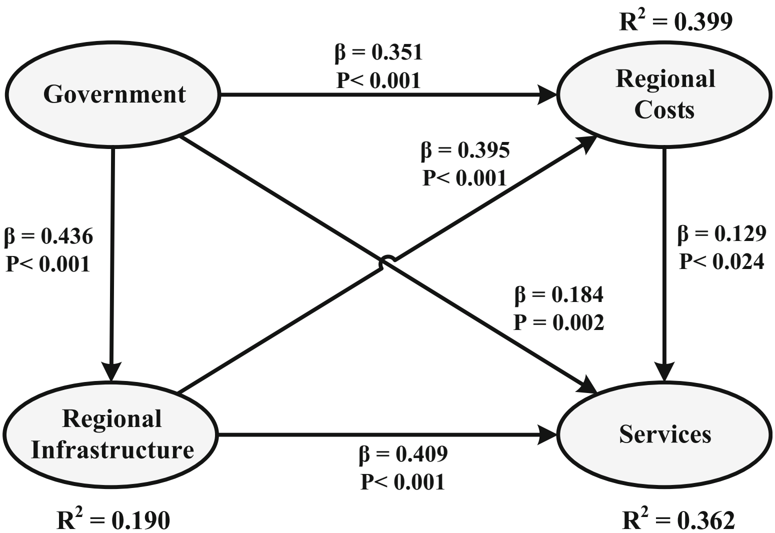

Fig. 12.8 Complex Model C evaluated: *Regional Factors*

12.6.1.3 Efficiency Indices of Complex Model C: *Regional Factors*

Ten model fit and quality indices must be estimated before interpreting the relationships. These indices are thoroughly discussed in the methodology chapter (see Chap. 9). The results of the model fit and quality evaluation for Model C are listed as follows:

- Average Path Coefficient (APC) = 0.317, $P < 0.001$
- Average R-Squared (ARS) = 0.317, $P < 0.001$
- Average Adjusted R-Squared (AARS) = 0.311, $P < 0.001$
- Average block VIF (AVIF) = 1.393, acceptable if ≤ 5, ideally ≤ 3.3
- Average Full collinearity VIF (AFVIF) = 1.577, acceptable if ≤ 5, ideally ≤ 3.3
- Tenenhaus GoF (GoF) = 0.458, small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36
- Simpson's Paradox Ratio (SPR) = 1.000, acceptable if ≥ 0.7, ideally = 1
- R-Squared Contribution Ratio (RSCR) = 1.000, acceptable if ≥ 0.9, ideally = 1
- Statistical Suppression Ratio (SSR) = 1.000, acceptable if ≥ 0.7
- Nonlinear Bivariate Causality Direction Ratio (NLBCDR) = 1.000, acceptable if ≥ 0.7

On average, all the relationships are statistically significant since the value of APC is lower than 0.005. Furthermore, according to ARS and AARS—both with a P value lower than 0.05—the model has enough predictive validity. As for AVIF and AFVIF indices, which are lower than 3.3—they confirm that the four latent variables are free from collinearity problems. Meanwhile, the Tenenhaus GoF is visibly higher than the cutoff value and indicates a good model fit. Finally, according to the remaining indices, hypothesis directionality problems can be discarded.

12.6.1.4 Latent Variable Validation Complex Model C: *Regional Factors*

In structural equation modeling, latent variables must be individually validated, not only the model. Table 12.5 summarizes the results from this validation process. As can be observed, seven coefficients are estimated, as discussed in the methodology chapter.

The validation results demonstrate that all the dependent latent variables have enough parametric predictive validity. That is, R^2 and adjusted R^2 only show values higher than 0.02, while Q^2 values are always higher than 0 and similar to their corresponding R^2 values. As for the CAI and the composite reliability index, they confirm that all the latent variables have enough internal validity, since the values are higher than 0.7. Finally, since all AVE values are higher than 0.5 and all VIF values are lower than 3.3, we can conclude that the latent variables have enough convergent validity and are free from collinearity problems. The modeled relationships can now be interpreted.

Table 12.5 Latent variable validation complex Model C: *Regional Factors*

Coefficient	Regional infrastructure	Government	Regional costs	Services
R-Squared (R^2)	0.190		0.398	0.362
Adjusted R^2	0.187		0.393	0.354
Composite reliability	0.842	0.919	0.827	0.941
Cronbach's alpha index (CAI)	0.749	0.889	0.737	0.874
Average variance extracted (AVE)	0.571	0.698	0.493	0.888
Full collinearity VIF	1.670	1.440	1.628	1.571
Q-Squared (Q^2)	0.189		0.398	0.365

12.6.1.5 Direct Effects

The model validation results depicted in Fig. 12.8 associate each relationship with a β value. According to this coefficient, the following conclusions can be proposed as regards the statistical significance, and thus the feasibility, of the model relationships.

H_1. In the manufacturing industry, there is enough statistical evidence to claim that *Government* support and management have a positive direct effect on *Regional Infrastructure*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.436 standard deviations.

H_2. In the manufacturing industry, there is enough statistical evidence to claim that *Government* support and management have a positive direct effect on infrastructure and services *Regional Costs*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.351 standard deviations.

H_3. In the manufacturing industry, there is enough statistical evidence to claim that *Government* support and management have a positive direct effect on the availability of regional *Services,* since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.184 standard deviations.

H_4. In the manufacturing industry, there is enough statistical evidence to claim that *Regional Infrastructure* has a positive direct effect on infrastructure and service *Regional Costs,* since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.395 standard deviations.

H_5. In the manufacturing industry, there is enough statistical evidence to claim that *Regional Infrastructure* has a positive direct effect on the availability and quality of regional *Services*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.409 standard deviations.

H_6. In the manufacturing industry, there is enough statistical evidence to claim that the level of competitiveness of *Regional Costs* has a positive direct effect on

Services availability and quality. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.129 standard deviations.

The industrial implications of these results can be discussed as follows:

- The *Government* must be the main *Infrastructure* and *Services* provider. In fact, the relationship between the *Government* and *Regional Infrastructure* shows the highest β value. Moreover, the *Government* has a positive direct effect on regional infrastructure costs and service costs.
- *Regional Infrastructure* is vital for *Services* availability and thus for supply chain performance. The β value of this relationship is the second highest in model C (i.e., $\beta = 409$).
- The smallest effect as indicated by β concerns the relationship between *Regional Costs* and *Services*. Such results imply that as service costs increase companies consume less of them.

12.6.1.6 Effect Sizes

As Fig. 12.8 depicts, the model has three dependent latent variables: *Regional Infrastructure*, *Costs*, and *Services*, which have an estimated R^2 value. This subsection decomposes the value of R^2 from each dependent latent variable to determine the amount of explained variance. The results of this analysis are summarized in Table 12.6.

Notice that latent variable *Regional Infrastructure* can always be explained through *Government* in 19% ($R^2 = 0.19$). However, the remaining two dependent latent variables do depend on at least two independent latent variables. In this sense, together both *Regional Infrastructure* and *Government* can explain 39.9% of the variance of *Regional Costs*. That being said, the former is slightly more important than the latter, as a consequence of its explanatory power. On the other hand, three latent variables can explain, together, 36.2% of the variance of *Services*, yet latent variable *Regional Infrastructure* has the highest explanatory power. In other words, *Services* greatly depend on *Regional Infrastructure*, which in turn depends on *Government* support and management policies.

Table 12.6 Effect sizes in complex Model C

To	From			R^2
	Regional infrastructure	Government	Regional costs	
Regional infrastructure		0.19		0.190
Regional costs	0.216	0.183		0.399
Services	0.227	0.078	0.057	0.362

12.6.1.7 Sum of Indirect Effects

Indirect effects occur in indirect relationships, when two latent variables are related through a third or more latent variables, known as mediators. In this model, latent variable *Government* can be indirectly related to the subsequent latent variables. Table 12.7 summarizes the indirect effects between the latent variables.

According to the *P* values, all the indirect relationships are statistically significant. However, the relationship between *Regional Infrastructure* and *Services* is barely significant, since $P = 0.048$. Similarly, the results demonstrate that the indirect impact of *Government* on *Services* is the largest in terms of magnitude. It is even higher than the direct effect. This implies that both *Regional Infrastructure* and *Regional Costs* must be considered to strengthen the relationship between *Government* support and *Services* availability; however, a clearer understanding of these results can be obtained after analyzing the total effects.

12.6.1.8 Total Effects

Total effects are the sum of the direct and indirect effects in a relationship. Table 12.8 presents the results of this analysis, whose conclusions can be discussed below:

- As indicated by the values of p, all the total effects are statistically significant at a 95% confidence level.
- The relationship between latent variables *Government* and *Regional Costs* has the largest effects in total, being $\beta = 0.524$. This demonstrates the importance of

Table 12.7 Sum of indirect effects in complex Model C

To	From	
	Regional infrastructure	Government
Regional costs		0.173 ($P < 0.001$) ES = 0.090
Services	0.051 ($P = 0.048$) ES = 0.028	0.246 ($P < 0.001$) ES = 0.104

Table 12.8 Total effects in complex Model C

To	From		
	Regional infrastructure	Government	Regional costs
Regional infrastructure		0.436 ($P < 0.001$) ES = 0.190	
Regional costs	0.395 ($P < 0.001$) ES = 0.2016	0.524 ($P < 0.001$) ES = 0.272	
Services	0.460 ($P < 0.001$) ES = 0.256	0.430 ($P < 0.001$) ES = 0.182	0.129 ($P = 0.024$) ES = 0.057

Government management for regional economic competitiveness, which should be improved by promoting foreign investment and jobs. However, notice that this relationship involves *Regional Infrastructure* as the mediator variable.

- The direct relationship between *Government* and *Services* is only $\beta = 0.184$, whereas the indirect relationship existing thanks to *Regional Infrastructure* and *Regional Costs* is visibly higher ($\beta = 0.246$). In total, the effect of this relationship is $\beta = 430$, which demonstrates that the *Government* is capable of providing the necessary services with the required quality when the *Regional Infrastructure* is properly managed and service costs are covered by the companies.
- According to the results depicted in Fig. 12.8, it is possible to provide a series of conclusions and discuss the industrial implications of the validated hypotheses. This discussion could support future decision making in the manufacturing industry.
- Even though the relationship between *Government* and *Regional Infrastructure* has the highest effects in total ($\beta = 0.436$), the value of the R^2 coefficient is relatively low ($R^2 = 0.190$). Such results indicate that there must be additional variables to explain the variability of the dependent latent variable. In other words, *Regional Infrastructure* does not depend solely on the *Government*, but is certainly associated with other variables, such as foreign investment quality and quantity.
- In this mode, Regional *Costs* depend on both *Government* support and *Regional Infrastructure.* The two latent variables are equally important, since the effect sizes are and the value of β are similar.
- Latent variable *Services* can be found in the bottom-right corner of the figure since it depends on all the remaining latent variables. Hence, it can be concluded that *Services* depend to a great extent on *Regional Infrastructure*, rather than on the *Government* or *Regional Costs.*

12.6.2 *Complex Model D:* Interrelations Among Regional Factors

The previous model analyzed four of the seven regional impact factors. The model proposed in this section analyzes the remaining factors with respect to the *Government* variable, again. The latent variables to be explored can be listed below:

- *Government*
- *Proximity*
- *Workforce*
- *Quality of Life*

This model assumes that *Government* can explain the remaining latent variables. This book assumes that governments, at all levels (federal, state, and local), have the responsibility to create the necessary conditions in which inhabitants can live as healthy and comfortable as possible. In this sense, *Government* support is reflected on the *Quality of Life* of its people. However, at a corporate level, supply chain success depends on how easily companies can reach suppliers and customers and how qualified the workforce is. The model that studies the relationships among the four aforementioned latent variables is depicted in Fig. 12.9. The model explores five research hypotheses.

12.6.2.1 Hypotheses Formulation: Complex Model D

This model explores the relationships about four regional factors in supply chain environments. The hypotheses here presented are commonly reported in the literature. Some of them have been actually tested, whereas some others have been merely proposed or discussed, which is why it is important to validate them statistically.

Governments are the major providers and implementers of economic development strategies. In corporate environments, governments directly and indirectly impact on a company's ability to settle in a given region and reach the desired economic growth. In this sense, government support positively influences supply chain performance in a variety of ways. According to Mancheri et al. (2018), the government plays an important role in the production of tantalum raw materials in the Congo Republic. Government policies allowed the tantalum supply chain to improve its performance, and they encouraged strategies for recycling other metals, thereby enabling tantalum suppliers to increase in number. Similarly, it has been argued that Mexico can increase its global competitiveness by providing the necessary conditions for foreign-own companies to settle in its territory. This can be

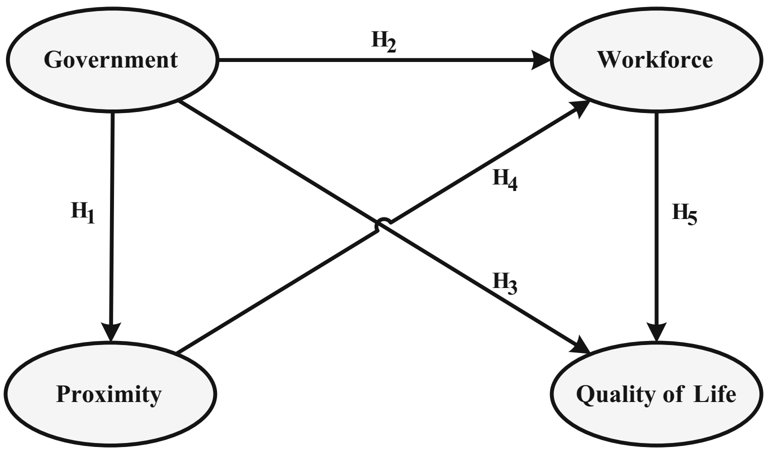

Fig. 12.9 Complex Model D proposed: *Regional Factors*

achieved through technology transfer and supply chain integration strategies and would allow established companies to advantage of the proximity to one of the largest global markets, the USA (Arroyo and Cruz-Mejía 2017).

Trade agreements are a decisive factor in economic growth, since public policies have a direct impact on the exchange of export-oriented goods (Sánchez-Reaza 2010). In this sense, market proximity is said to favor innovation and thus business competitiveness. Moreover, it promotes business design sophistication and sustainable process management (Moradinasab et al. 2018), thereby offering countries more development benefits. Finally, as claimed by Iimi et al. (2015), in order to increase economic competitiveness, companies must be located within industrial areas inside urban spaces. This would allow them to share benefits in terms of workforce, market entrance opportunities, and costs minimization. In this sense, the first research hypothesis of model D can be proposed as follows:

H_1. In the manufacturing industry, *Government* support and management have a positive direct effect on market *Proximity*, which enables to increase regional corporate innovation.

Governments play a decisive part not only in market *Proximity*, but also in terms of human resource factors. In addition to ensuring employee *Quality of Life* along the supply chain, *Government* actions should aim at providing the necessary health and safety conditions and policies that contribute to the emotional, cognitive, and physical well-being of employees as human beings (Ott 2011). Such conditions have an impact on resilient involvement and performance and thus on business productivity (Moradinasab et al. 2018). In other words, public policies established by the *Government* must promote social well-being through programs and projects that stimulate social participation. From this perspective, it can be argued that through economic and social development policies, *Governments* have an impact on employee performance and thus on business performance. Therefore, the second research hypothesis can read as follows:

H_2. In the manufacturing industry, *Government* support and management have a positive direct effect on *Workforce* abilities and skills.

As Fig. 12.9 suggests, *Quality of Life* depends on two main forces: an individual's personal life and his/her professional life (Johnston et al. 2010). On the one hand, human beings perform and live in social environments; their level of life satisfaction, cognitive, emotional, and physical health, introspective capabilities, and objectivity are evaluated through observable indicators. On the other hand, individuals rely on several instruments to perceive particular aspects of their life. From this perspective, it can be argued that the employees' perceptions on their *Quality of Life* can denote their level of involvement in the company. Thus, the benefits of education should be reflected on the ability of workers to be productive and add value to goods. In this sense, employee education increases individual well-being and income (Briceño Mosquera 2011).

According to Brugnoli and Gonnet (2015), *Governments* should design public policies that promote social participation and encourage local industrial growth, thereby providing greater job opportunities for local inhabitants. However, it is always important to take into account the physical and intellectual capabilities of the population; that is, their abilities and skills to perform productively. Finally, employees must be able to know and adapt to technological changes and economic aspects that occur both inside and outside of the company. This would provide them with economic stability and an appropriate *Quality of Life*. Under these premises, the third research hypothesis can be proposed below:

H_3. In the manufacturing industry, *Government* support and management have a positive direct effect on regional employee *Quality of Life*.

Empirical studies have proved that intellectual capital is a valuable competitive strategy, as it has a positive impact on corporate performance (Mehri et al. 2013; Mondal and Ghosh 2012). Likewise, Lara (2016) managed to identify important benefits that the Mexican export-oriented manufacturing industry offers its people thanks to its proximity to the United States. Foreign-owned companies established in Mexico have promoted skills and work grounds that had not been part of the Mexican workforce before, such as teamwork, work quality, and production process. In turn, these skills have led to important changes in the Mexican educational system and have highlighted the need to improve the skills and abilities of the working population.

Working in the export-oriented manufacturing industry implies using technological learning processes to compete with international markets. Moreover, skills such as decision making, increased technical abilities, and increased productivity are another reflection of the efforts made by the Mexican manufacturing industry over the years. Nowadays, newly developed skills and newly acquired knowledge and experiences among Mexican workers are notice as knowledge transferred promoted thanks to the establishment of export-oriented manufacturing companies in the country (Limón and Corral 2011). Following this discussion, it is possible to argue that Mexico's *Proximity* to the USA has an impact on its *Workforce* as a result of the exigencies of new production approaches and international competitive strategies. In this sense, the fourth research hypothesis is stated as follows:

H_4. In the manufacturing industry, *Proximity* to customers and suppliers has a positive direct impact on a region's *Workforce*.

Adaptation is another important *Workforce* skill. Employees should be able to adapt to those environmental factors that change to preserve a stable well-being (Urzúa and Caqueo 2012). Such factors are usually influenced by regional economic growth aspects. Additionally, manufacturing companies should be settled within industrial ecosystems or areas that enable them to strengthen their social, industrial, and environmental relationships. Nowadays, all the regional industries have a joint impact on the *Quality of Life* of the regional population, as well as on the region's competitiveness and worldwide prestige (Scheel 2012).

Similarly, education contributes to the generation of incomes. People develop skills and acquire knowledge that allow them to increase their productive and social capabilities, thereby generating higher income and wealth and achieving a greater well-being and better social cohesion (Briceño Mosquera 2011). In conclusion, *Workforce* benefits such as education and professional development contribute to a better *Quality of Life*. In this sense, the fifth research hypothesis can be proposed below:

H_5. In the manufacturing industry, regional *Workforce* has a positive direct impact on regional *Quality of Life*.

12.6.2.2 Results of Complex Model D: *Regional Factors*

The results of the model evaluation process are depicted in Fig. 12.10. Each relationship between two latent variables is associated with three coefficients. The β coefficient is a measure of dependency, whereas R^2 indicates the amount of variance in a dependent latent variable that is explained by independent latent variables. Finally, the P value indicates the statistical significance of the relationship. P values lower than 0.05 indicate statistically significant relationships.

According to the evaluation results, it is possible to conclude the following:

- All the relationships between the latent variables are statistically significant.
- The dependent latent variables have enough predictive validity, since the R^2 coefficient is always higher than 0.02.

12.6.2.3 Efficiency Indices of Complex Model D: *Regional Factors*

Ten indices were estimated to measure the model's quality and fit. The evaluation was performed as discussed in the methodology chapter (see Chap. 9). The results of the model evaluation are listed below:

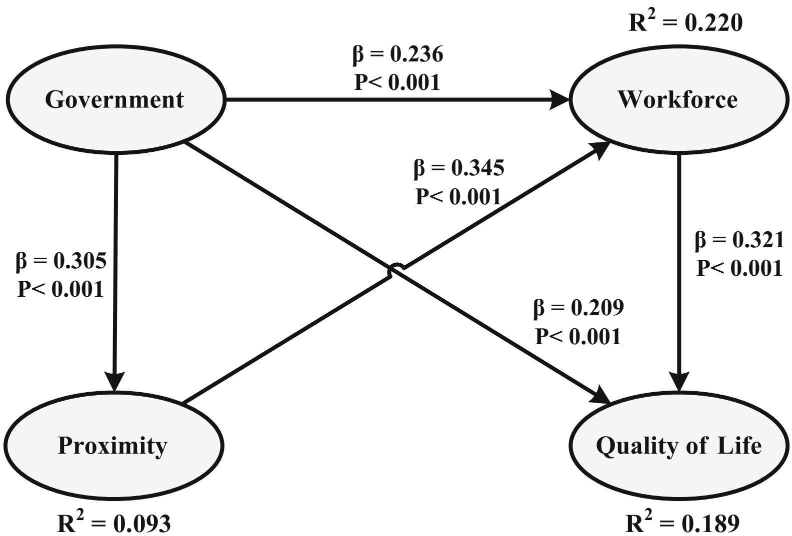

Fig. 12.10 Complex Model D evaluated: *Regional Factors*

- Average Path Coefficient (APC) = 0.283, $P < 0.001$
- Average R-Squared (R^2) (ARS) = 0.167, $P = 0.003$
- Average Adjusted R-Squared (AARS) = 0.161, $P = 0.003$
- Average block VIF (AVIF) = 1.092, acceptable if ≤ 5, ideally ≤ 3.3
- Average Full collinearity VIF (AFVIF) = 1.224, acceptable if ≤ 5, ideally ≤ 3.3
- Tenenhaus GoF (GoF) = 0.383, small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36
- Simpson's Paradox Ratio (SPR) = 1.000, acceptable if ≥ 0.7, ideally = 1
- R-Squared Contribution Ratio (RSCR) = 1.000, acceptable if ≥ 0.9, ideally = 1
- Statistical Suppression Ratio (SSR) = 1.000, acceptable if ≥ 0.7
- Nonlinear Bivariate Causality Direction Ratio (NLBCDR) = 1.000, acceptable if ≥ 0.7

As can be observed, all the existing relationships between latent variables are statistically significant, since the P value of APC is lower than 0.5. Moreover, the model has enough predictive validity since both ARS and AARS have P values lower than 0.5. On the other hand, AVIF and AFVIF confirm that the model is free from collinearity problems, since their values are lower than 3.3. As for the goodness of fit (Tenenhaus GoF), we can conclude that the model has a good fit. Finally, as indicated by SPR, RSCR, SSR, and NLBCDR, the model is free from directionality problems in the hypotheses.

12.6.2.4 Latent Variable Validation Complex Model D: *Regional Factors*

The results from the validation tests performed on the four latent variables are summarized in Table 12.9. The estimated coefficients indicate enough parametric and nonparametric validity, good internal validity and convergent validity, and no collinearity problems. Likewise, we found similar values for latent variable *Government* in both this model and the previous one. Also observe that *Proximity* Cronbach's alpha is lower that 0.7, because has a value of 0.640. Following these results, the model can be interpreted.

12.6.2.5 Direct Effects

According to the previous validation results, it is possible to propose the following conclusions as regards the relationships between latent variables:

H_1. In the manufacturing industry, there is enough statistical evidence to claim that *Government* support and management has a positive direct effect on *Proximity* to suppliers and customers, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.305 standard deviations.

Table 12.9 Latent variable validation in complex Model D: *Regional Factors*

Coefficient	Workforce	Government	Proximity	Quality of life
R-Squared (R^2)	0.220		0.093	0.187
Adjusted R^2	0.213		0.089	0.180
Composite reliability	0.885	0.919	0.807	0.884
Cronbach's alpha index (CAI)	0.805	0.889	0.640	0.824
Average variance extracted (AVE)	0.720	0.698	0.584	0.658
Full collinearity VIF	1.312	1.193	1.199	1.191
Q-Squared (Q^2)	0.224	–	0.093	0.186

H_2. In the manufacturing industry, there is enough statistical evidence to claim that *Government* support and management has a positive direct effect on *Workforce,* since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.236 standard deviations.

H_3. In the manufacturing industry, there is enough statistical evidence to claim that *Government* support and management has a positive direct effect on regional *Quality of Life,* since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.209 standard deviations.

H_4. In the manufacturing industry, there is enough statistical evidence to claim that *Proximity* to suppliers and customers has a positive direct effect on regional *Workforce*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.345 standard deviations.

H_5. In the manufacturing industry, there is enough statistical evidence to claim that regional *Workforce* has a positive direct effect on regional *Quality of Life,* since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.321 standard deviations.

12.6.2.6 Effect Sizes

In this model, two dependent latent variables are explained by two independent latent variables; therefore, it is important to decompose the value of explained variance (i.e., R^2). Table 12.10 summarizes the results of the variance decomposition for each dependent latent variable. According to such results, the following conclusions can be proposed:

- *Government* and *Proximity* together explain 22% of latent variable *Workforce*; the former explains 7.8% of the variability, whereas the latter explains 14.2%. Such results imply that *Government* actions and support determine to some extent the competitiveness and skillfulness of the regional *Workforce*, since it is the main provider of education. However, workforce quality is mostly the result of a competitive market environment.

Table 12.10 Effect sizes in complex Model D

To	From			R^2
	Workforce	Government	Proximity	
Workforce		0.078	0.142	0.220
Proximity		0.093		0.093
Quality of life	0.125	0.064		0.189

- *Workforce* and *Government* together explain 18.9% of the variability of *Quality of Life*. The former explains 12.5%, whereas the latter explains 6.4%. These results indicate that even though *Government* support and actions are important, employee skills and abilities are more important to reach a proper *Quality of Life*.

12.6.2.7 Sum of Indirect Effects

Some latent variables can be indirectly interrelated to each other through additional latent variables, known as mediators. Such indirect relationships also have important effects. Table 12.11 below summarizes the indirect effects between the latent variables of the model.

As can be observed, latent variable *Government* has indirect effects on both *Quality of Life* and *Workforce*. Such indirect effects are higher when compared to the direct effects. Similarly, the *P* value of the indirect relationship between *Proximity* and *Quality of Life* demonstrates that being close to both suppliers and customers allows the manufacturing industry to contribute to a good *Quality of Life* for the regional population.

12.6.2.8 Total Effects

All relationships between latent variables have total effects, which are the sum of both direct and indirect effects. The total effects found in the model are reported in Table 12.12 and can be interpreted as follows:

Table 12.11 Sum of indirect effects in complex Model D

To	From	
	Government	Proximity
Workforce	0.105 (P = 0.012) ES = 0.035	
Quality of life	0.110 (P = 0.009) ES = 0.034	0.111 (P = 0.009) ES = 0.018

Table 12.12 Total effects in complex Model D

To	From		
	Workforce	Government	Proximity
Workforce		0.342 (*P* = 0.001) ES = 0.113	0.345 (*P* = 0.001) ES = 0.142
Proximity		0.305 (*P* = 0.001) ES = 0.093	
Quality of life	0.321 (*P* = 0.001) ES = 0.123	0.319 (*P* = 0.001) ES = 0.098	0.111 (*P* = 0.009) ES = 0.018

- All the total effects are statistically significant at a 95% confidence level, since their *P* values are lower than 0.05.
- *Workforce* has the largest explanatory power. In its relationship with *Quality of Life*, the total effect size is 0.123, one of the largest.
- Even though a relationship between *Proximity* and *Quality of Life* is not reported, the former has clearly an impact on the latter, being ES = 0.018.

12.6.2.9 Final Conclusions for Complex Model D: *Regional Factors*

According to the information provided by the model on the relationships among regional impact factors in the manufacturing industry, it is possible to propose the following concluding remarks:

- The *Government* must be the main manager of regional factors that impact on supply chain performance. Such management actions must be reflected on both operational advantages for shareholders and a better regional *Quality of Life*. This is the only way of ensuring supply chain success.
- Even though the *Government* must be the main regional manager, educational institutions and healthcare systems are a key in industrial development. In this sense, the regional *Workforce*, through its skills and knowledge, plays a crucial role in regional *Quality of Life*. In other words, well-being is not only the responsibility of the *Government*, but it also depends on the desire of the people to succeed and move forward.
- The *Government* must facilitate the development of market environments, where buyers and vendors interact easily and closely. This is a good way to increase *Workforce* abilities and skills, and thus competitiveness.

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Chapter 13
Models of Regional Factors—Supply Chain Performance (Benefits)

13.1 Complex Models: Regional Factors—Benefits

The goal of this model is to explore the relationships between two external variables and two supply chain performance benefits. In other words, aspects such as infrastructure and government support are important for companies to operate, yet they cannot be controlled inside of the facilities and depend on external forces. The first model analyzes the relationship between regional factors (*Government, Regional Infrastructure*) on performance (*Flexibility, Delivery Times*).

13.1.1 Complex Model A: Regional Factors—Benefits

Two of the latent variables in this model represent regional factors, whereas two other represent supply chain *Performance* benefits. They are all listed below:

As *Regional Factors*, this model explores:

- *Government*
- *Regional Infrastructure*

As supply chain performance *Benefits*, the model studies:

- *Flexibility*
- *Delivery Times*

For further information on the observed variables comprised in the latent variables, please refer to the methodology chapter. Likewise, Fig. 13.1 illustrates the proposed model, where the different interactions or research hypotheses between latent variables can be observed. These hypotheses will be thoroughly discussed in the following section.

L. Avelar-Sosa et al., *Evaluation of Supply Chain Performance*,
Management and Industrial Engineering,
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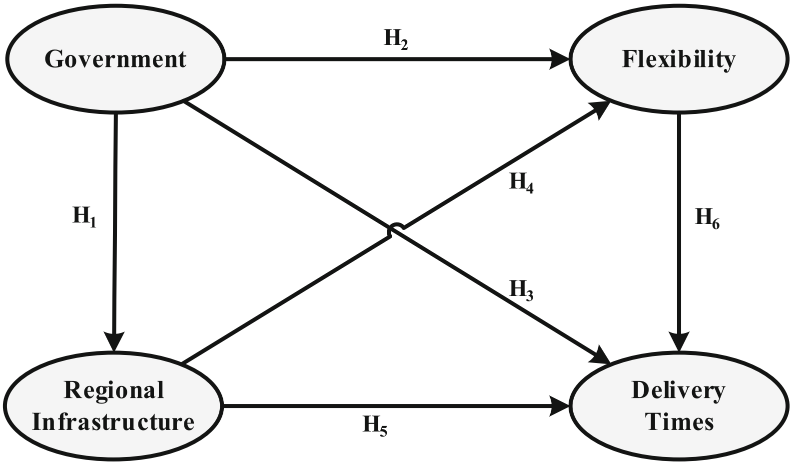

Fig. 13.1 Complex Model A proposed: *Regional Factors—Benefits*

13.1.1.1 Hypothesis Formulation: Complex Model A

The two regional factors can be found on the left side of the model, whereas the two supply chain performance benefit variables can be found on the right. The model depicts six research hypotheses. Some of them were initially proposed and tested in the previous chapter (see Chap. 12, simple complex models); however, effects in relationships can change as new or different variables interact in a model. Therefore, it is important to test the hypotheses every time the model is different. Likewise, the model assumes that *Government* is the independent latent variable that is why it is located in the top-left corner of the figure. On the other hand, *Regional Infrastructure* and *Flexibility* explain *Delivery Times*, which is thus located in the bottom-right corner and is considered as the dependent latent variable. The six research hypotheses that connect the variables are illustrated below and discussed in the following paragraphs.

Regional *Governments* have the responsibility to enhance local infrastructure and promote it as a competitive advantage among industries looking to settle down in the region (Harrison and New 2002). Moreover, federal, local, and regional taxes must be returned to the society in the form of appropriate infrastructure and services that contribute to both regional economic development and quality of life. However, governmental commitment does not stop there; both local infrastructure and services must be appropriately and consistently managed in order to minimize potential risks, especially in terms of roads and airports (Blümel et al. 2008; Viljoen and Joubert 2017). In this sense, governments have to design and implement infrastructure generation strategies that facilitate corporate operations, including virtual supply chains, telecommunication services, banking services, and legal services, among others (Verdouw et al. 2016). Finally, *Governments* also tend to rely on co-investment with private corporations to generate the necessary regional infrastructure and services for companies to operate successfully. On the one hand, co-investment enables governments to solve shortcomings; on the other hand, investing companies receive remuneration for leasing their use (Kogan and Tapiero 2012). Therefore, considering the role of *Governments* at all levels in *Infrastructure* development and availability, the first research hypothesis is proposed as follows:

H_1. In the manufacturing industry, regional *Government* actions and management have a positive direct impact on *Regional Infrastructure*.

Flexibility is another important aspect of supply chain systems. Among the multiple sources of *Flexibility*, the *Government* is one of the most important. Labor regulations have a direct impact on work *Flexibility*, as countries and regions have specific labor regulations and laws. Such regulations can generate some level of uncertainty (Sreedevi and Saranga 2017) that might be difficult to minimize along the supply chain (Chatzikontidou et al. 2017). Likewise, each *Government* offers its own education system and services and thus plays a particular role in regional workforce skill and ability acquisition. Regions characterized by a highly-trained and skilled workforce facilitate *Flexibility* (Sendlhofer and Lernborg 2017). They allow companies to easily adjust their production systems and offer a wider range of products and services without neglecting their environmental impact (Tramarico et al. 2017). Moreover, *Government* regulations and requirements mainly determine the speed at which companies can undergo obligatory governmental procedures. Following this discussion, the second research of Modela A can be stated as follows:

H_2. In the manufacturing industry, regional *Government* actions and management have a positive direct impact on supply chain *Flexibility*.

In the industrial sector, *Government* support can be either a competitive advantage or a source of risk. It can either streamline or hinder *Delivery Times*, depending on its stability. For instance, regulations for handling hazardous materials must be supported by adequate and specialized *Infrastructure* (Ma and Li 2017). Similarly, appropriate maintenance and maintenance regulations must be provided for roads and all distribution channels used for product and service distribution (Kogan and Tapiero 2012). Undoubtedly, low-quality or inappropriate transportation channels can compromise timely deliveries and thus customer satisfaction. In fact, research supports the claim that little or no governmental support in transportation services compromises export-oriented operations (Bayer et al. 2009). In order to explore this relationship between government actions and delivery times, the fourth research hypothesis for Model A can be proposed below:

H_3. In the manufacturing industry, regional *Government* actions and management have a positive direct impact on supply chain *Delivery Times*.

Regional Infrastructure is another source of supply chain *Flexibility*, as it provides different means of transportation. If roads are blocked, regions must count on the necessary infrastructure to allow companies to operate successfully through other transportation alternatives. In addition to product or service delivery, changeovers are a clear example of important corporate operations. Rapid changeovers can be achieved only if companies have the necessary machine components, a skilled workforce, and a supportive *Infrastructure* (Mendes et al. 2016). Finally, *Regional Infrastructure* provides *Flexibility* to manufacturing companies through the availability of facilities and services, such as warehouses, the Internet, and communication systems (Accorsi et al. 2017). In this sense, the third research hypothesis of this model can be proposed below:

H_4. In the manufacturing industry, *Regional Infrastructure* has a positive direct impact on supply chain *Flexibility*.

Delivery Times is a common supply chain performance indicator that can be compromised not only by little government support, but also by a lack of *Infrastructure*. The absence or little availability of transportation channels, such as roads and airports, has an impact on product and service prices. Since the 1980s, governments have focused their efforts on developing proper and efficient land and sea routes and *Infrastructure*, including ports, to encourage regional development (Wiese 1981). Nevertheless, to guarantee *Flexibility* in terms of *Delivery Times,* such *Infrastructure* elements must be interconnected and fully integrated (Saidi et al. 2018), as this robustness and reliability can counteract operational risks (Sreedevi and Saranga 2017). That said, the relationship between *Regional Infrastructure* and *Delivery Times* in the manufacturing industry can be explored throughout the following research hypothesis:

H_5. In the manufacturing industry, *Regional Infrastructure* has a positive direct impact on *Delivery Times*.

Flexibility has an impact on *Delivery Times*. Companies that rely on a single distribution channel have little *Flexibility* and thus are more prone to distribution and transportation risks (Nouri Gharahasanlou et al. 2017). In fact, experts recommend trusting more than one delivery channel or route. Similarly, production processes that are not flexible enough can compromise timely deliveries. If changeovers are slow, SMED programs do not operate properly (Rodríguez-Méndez et al. 2015), or JIT systems are poorly implemented in the production lines, and products or services might fail to be delivered on time as promised by the company (Green et al. 2014). In this sense, inappropriate SMED and JIT implementation are usually the result of employee underperformance. Employees might lack the necessary skills and training to become experts in something that is not part of their professional expertise. As a result of this discussion, it is possible to explore the relationship between *Flexibility* and *Delivery Times* throughout the following research hypothesis:

H_6. In the manufacturing industry, corporate *Flexibility* has a positive direct impact on *Delivery Times*.

13.1.1.2 Latent Variable Validation of Complex Model A

Table 13.1 summarizes the results of the validity tests performed on the latent variables. The tests were conducted as discussed in the methodology chapter, and the results were initially provided in the last chapter.

According to the methodology followed in this work (see Chap. 9), the three dependent latent variables have enough predictive validity from both parametric and nonparametric perspectives; that is, coefficients R^2 and adjusted R^2 are higher than 0.02 and similar to their corresponding Q^2 values. On the other hand, the internal validity of the data is confirmed thanks to the CAI and the composite reliability index, whose values are higher than 0.7 in all the latent variables. As for AVE, it confirms convergent validity, whereas VIF demonstrates that the latent variables are free from internal collinearity problems. The model can now be assessed and interpreted accordingly.

13.1.1.3 Results of Complex Model A: *Regional Factors—Benefits*

Notice that every direct relationship between two latent variables corresponds to a research hypothesis and is associated with two coefficients: β is a measure of dependency, whereas P value indicates the statistical significance of the relationship and thus of the effect. Relationships with P values lower than 0.05 are statistically significant at a 95% confidence level. Finally, an R^2 value is provided for each dependent latent variable as a measure of explained variance.

13.1.1.4 Model Fit and Quality Indices in Complex Model A: *Regional Factors—Benefits*

By integrating the latent variables in the model, it is suitable to identify their efficiency indices in order to conclude better on them, and they are as follows:

Table 13.1 Latent variable validation complex Model A: *Regional Factors—Benefits*

Coefficients	Government	Regional infrastructure	Flexibility	Delivery times
R-Squared (R^2)		0.190	0.094	0.277
Adjusted R-squared		0.187	0.086	0.267
Composite reliability	0.919	0.842	0.854	0.840
Cronbach's alpha index (CAI)	0.889	0.749	0.795	0.618
Average variance extracted (AVE)	0.698	0.571	0.505	0.724
Full collinearity VIF	1.212	1.257	1.354	1.348
Q-squared (Q^2)		0.189	0.099	0.278

- Average Path Coefficient (APC) = 0.246, $P < 0.001$
- Average R-Squared (R^2) (ARS) = 0.187, $P = 0.001$
- Average Adjusted R-Squared (AARS) = 0.180, $P = 0.001$
- Average block VIF (AVIF) = 1.215, acceptable if ≤ 5, ideally ≤ 3.3
- Average Full collinearity VIF (AFVIF) = 1.292, acceptable if ≤ 5, ideally ≤ 3.3
- Tenenhaus GoF (GoF) = 0.341, small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36
- Simpson's Paradox Ratio (SPR) = 1.000, acceptable if ≥ 0.7, ideally = 1
- R-Squared Contribution Ratio (RSCR) = 1.000, acceptable if ≥ 0.9, ideally = 1
- Statistical Suppression Ratio (SSR) = 1.000, acceptable if ≥ 0.7
- Nonlinear Bivariate Causality Direction Ratio (NLBCDR) = 1.000, acceptable if ≥ 0.7

According to the P values of both ARS and AARS (both lower than 0.05), the model has enough predictive validity. Similarly, AVIF and AFVIF—whose values are lower than 3.3—confirm that the model is free from collinearity problems. As for the Tenenhaus GoF, it suggests a good model fit. Finally, the values of the remaining four indices imply that the hypotheses are free from causality direction problems. The model can now be interpreted accordingly.

13.1.1.5 Direct Effects

Direct effects are usually employed to statistically test research hypotheses previously proposed. In this model, the tested direct effects are depicted in Fig. 13.2 and can be interpreted as follows:

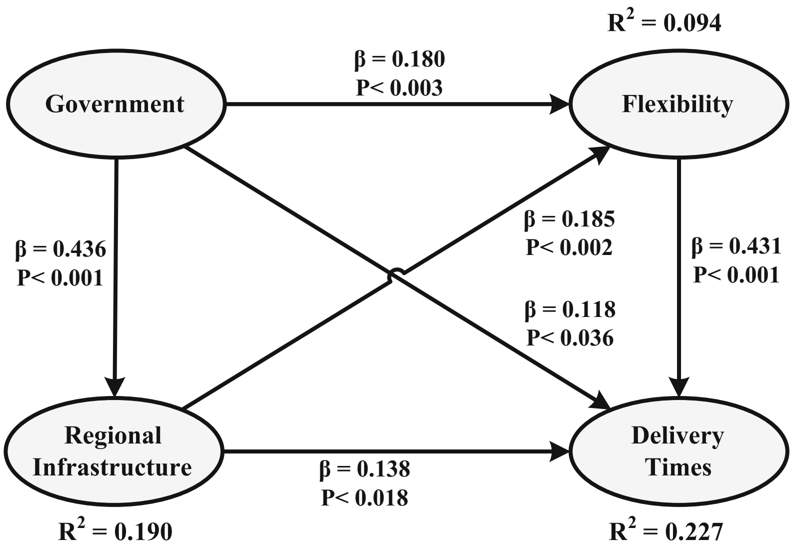

Fig. 13.2 Complex Model A evaluated: *Regional Factors—Benefits*

H_1. In the manufacturing industry, there is enough statistical evidence to claim that *Government* actions and management have a positive direct impact on *Regional Infrastructure*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.436 standard deviations.
H_2. In the manufacturing industry, there is enough statistical evidence to claim that *Government* actions and management have a positive direct impact on supply chain *Flexibility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.180 standard deviations.
H_3. In the manufacturing industry, there is enough statistical evidence to claim that *Government* actions and management have a positive direct impact on *Delivery Times*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.118 standard deviations.
H_4. In the manufacturing industry, there is enough statistical evidence to claim that *Regional Infrastructure* has a positive direct impact on supply chain *Flexibility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.185 standard deviations.
H_5. In the manufacturing industry, there is enough statistical evidence to claim that *Regional Infrastructure* has a positive direct impact on *Delivery Times*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.138 standard deviations.
H_6. In the manufacturing industry, there is enough statistical evidence to claim that corporate *Flexibility* has a positive direct impact on *Delivery Times*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.431 standard deviations.

13.1.1.6 Effect Sizes

When the variability of a dependent latent variable depends on two or more independent latent variables, R^2 must be decomposed to determine how much variability can be explained by each one of the independent latent variables. The decomposition of this variability is illustrated in Table 13.2; the last column indicates the value of R^2 for each of them, note that the sum of the sizes of the effects is equal to this value. Each portion or percentage of variability is known as effect size.

Table 13.2 Effect sizes complex Model A

To	From			R^2
	Government	Regional infrastructure	Flexibility	
Regional infrastructure	0.190			0.19
Flexibility	0.046	0.048		0.094
Delivery times	0.033	0.041	0.203	0.277

Based on the aforementioned results and the model presented in Fig. 13.2, it is possible to conclude the following:

- Together, *Government* and *Regional Infrastructure* explain 9.4% of the variability of *Flexibility,* since R^2 = 0.94. This percentage is large enough to claim that the variability of the dependent variable is statistically relevant. However, since the two effect sizes are similar, it might be challenging to accurately determine which of the two have independent variables—*Government* or *Regional Infrastructure*—has the strongest influence on *Flexibility*.
- Three latent variables explain 27% of the total variance of *Delivery Times*, as R^2 = 0.27, yet as Table 13.2 indicates, *Flexibility* has the largest influence, since ES = 0.203. Such results imply that particular attention must be paid to corporate *Flexibility* as a delivery time compliance strategy.

13.1.1.7 Sum of Indirect Effects

Two latent variables can be related through additional latent variables, known as mediators. Indirect effects in indirect relationships can be tracked by following two or more model paths. Table 13.3 reports the indirect effects found in Model A. As previously mentioned, β is a measure of dependency, whereas *P* value indicates the statistical significance of the relationship and thus of the effect. Relationships with *P* values lower than 0.05 are statistically significant at a 95% confidence level.

At first glance, the indirect relationship between *Government and Delivery Times* might seem surprising, as the effect is significantly higher (i.e., 0.170) if compared to the direct effect, estimated in the previous section (i.e., 0.118). Such results indicate that *Government* support and management have a larger impact on *Delivery Times* when *Flexibility* and *Regional Infrastructure* are involved. In other words, *Governments* are managers of those resources that facilitate corporate operations and thus functioning.

Table 13.3 Sum of indirect effects in complex Model A

To	From	
	Government	Regional infrastructure
Flexibility	0.081 (*P* = 0.042) ES = 0.021	
Delivery times	0.170 (*P* = 0.042) ES = 0.047	0.078 (*P* = 0.042) ES = 0.023

13.1.1.8 Total Effects

If interpreted independently, direct and indirect effects do not provide a holistic approximation of the importance of the latent variables and their relationships. Therefore, a more accurate analysis requires the interpretation of the total effects, which is the sum of both direct and indirect effects. Table 13.4 summarizes the results obtained after estimating the total effects in the relationships between the latent variables.

According to the results obtained and summarized on the abovementioned table, it is possible to propose the following conclusions as regards the total effects between the latent variables:

- The six effects are statistically significant at a 95% confidence level, since the *P* values are lower than 0.05.
- Two relationships report the largest total effects: that between *Flexibility* and *Delivery Times* and that between *Government* and *Regional Infrastructure* (ES = 0.080).
- The two largest effects are also direct effects; that is, not indirect effects were found in these relationships.
- Total effects only increase for latent variables *Flexibility* and *Delivery Times*, as two mediator variables intervene.
- The relationship between *Government* and *Delivery Times* is mostly significant thanks to the indirect effects. The effects go from 0.118 (direct) to 0.288 (total), thereby demonstrating the importance of *Flexibility* and *Regional Infrastructure*.

13.1.1.9 Conclusions and Limitations for Model A: *Regional Factors—Benefits*

This model explores the relationships between *Regional factors* and two supply chain *Performance* benefits. The following findings can be highlighted:

- The model has low explanatory power, since the values of R^2 in the independent latent variables are low. Therefore, more latent variables are necessary explain the variability of the model.

Table 13.4 Total effects in complex Model A

To	From		
	Government	Regional infrastructure	Flexibility
Regional infrastructure	0.436 ($P < 0.001$) ES = 0.190		
Flexibility	0.260 ($P < 0.001$) ES = 0.067	0.185 ($P = 0.002$) ES = 0.048	
Delivery times	0.288 ($P < 0.001$) ES = 0.080	0.215 ($P < 0.001$) ES = 0.064	0.421 ($P < 0.001$) ES = 0.203

- According to Table 13.2, the largest total effects are direct, where the role of moderator variables is little significant. Such results confirm the low β values in the other relationships.
- The direct relationship between *Government* and *Delivery Times* shows $\beta = 0.118$, while the indirect effect shows $\beta = 0.170$. In total, the relationship between these variables is $\beta = 0.288$. Such results demonstrate the importance of mediator variables. In other words, managers must focus their efforts on obtaining *Regional Infrastructure* through the *Government* and *Flexibility* through *Regional Infrastructure*.

In conclusion, a lack of government support in terms of investment protection, operational transparency, and infrastructure availability has a negative impact on corporate performance, especially in delivery time performance. In this sense, the companies surveyed for this research consider that the supply chain risks at which they are exposed are rather the consequence of poor or little governmental support than the result of internal incosistencies.

13.1.2 *Complex Model B:* Regional Factors—Benefits

This model relates two more regional factors with two more supply chain performance benefits. The model assumes that economic or financial benefits in supply chain systems depend on costs incurred in land, infrastructure, human resources, and business support services (banks, transportation, accounting bureaus, etc.). However, costs in supply chain systems also depend on their availability and demand. Therefore, experts usually analyze operational aspects, such as supplier proximity and availability, local competition, and market proximity. Since both *Regional Costs* and *Proximity* surely have an impact on *Financial Performance*, the following model seeks to integrate these variables.

The model integrates economic aspects that can be associated with supply chain performance. In this sense, the *Regional Impact Factors* to be explored are listed as follows:

- *Regional Costs* (five items or observed variables)
- *Proximity* (three items or observed variables)

As regards the supply chain performance benefits to be analyzed, they are listed below:

- *Transportation* (three items or observed variables)
- *Financial Performance* (three items or observed variables)

For more information on the items or observed variables comprised in these latent variables, please refer to the methodology chapter.

This model integrates four latent variables two related to economic or financial performance, and other two related *Regional factors*. The goal is to determine the impact of *Costs* incurred in infrastructure and services on supply chain *Financial Performance*. To this end, the model proposes six research hypotheses. Latent variable *Regional Costs* is placed in the top-left corner and is thus considered as the independent latent variable, the latent variable *Transportation* is placed in the top-right corner and is a dependent variable. It is believed to explain all the remaining factors. The model is shown in Fig. 13.3 and depicts related the aforementioned latent variables.

The model also takes into account market *Proximity* such as costs incurred in raw material supply and customers. Similarly, *Financial Performance* is placed in the bottom-right corner of the model, as it is considered to be the final goal of company performance. However, it depends on *Transportation* benefits obtained along the supply chain.

13.1.2.1 Hypothesis Formulation: Complex Model B

This model explores the relationships about four regional factors in supply chain environments. The hypotheses here presented are commonly reported in the literature. Some of them have been actually tested, whereas some others have been merely proposed or discussed, which is why it is important to validate them statistically.

The following paragraphs briefly discuss and justify these hypotheses.

Costs are one of the most important factors to be analyzed before companies settle down in a region. In fact, labor costs are the main reason why the Mexican manufacturing industry exists. Foreign-owned companies locate in Mexico in order

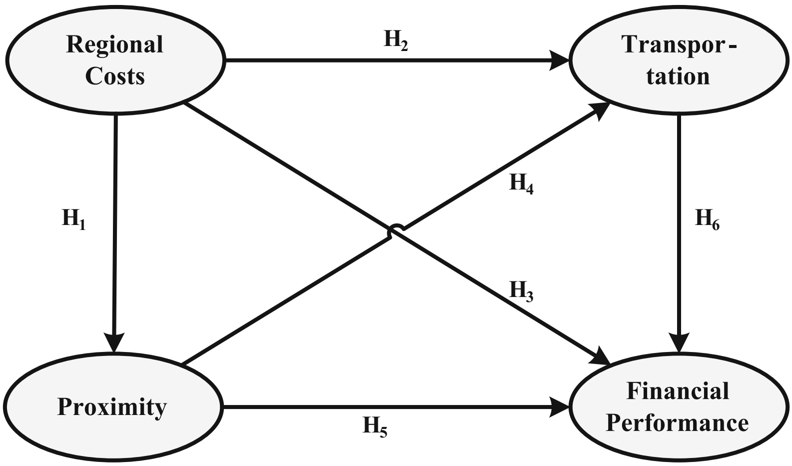

Fig. 13.3 Complex Model B proposed: *Regional Factors—Benefits*

to take advantage of a relatively cheap and highly qualified workforce (Hadjimarcou et al. 2013; Utar and Ruiz 2013), attractive tariffs, and free trade agreements (Cervantes-Martínez et al. 2016; Sayogo et al. 2015).

Additionally, Mexico provides foreign industries customer proximity, and thus opportunities for cost minimization in terms of transport, especially in border cities. Industries established in border regions, such as Ciudad Juárez, have greater proximity to one of the largest and most important markets: the USA (Alcaraz et al. 2014; Sargent and Matthews 2004). However, companies must also take into account those costs incurred in equipment maintenance (Dowlatshahi 2008) and custom services (Vargas and Johnson 1993). Following this discussion, the relationship between *Regional Costs* and *market Proximity* can be explored through the following research hypothesis:

H_1. In the manufacturing industry, *Regional Costs* have a positive direct effect on market *Proximity*.

In the manufacturing industry, *Regional Costs* associated with public services and support (e.g., *Transportation* systems) can have either positive or negative effects on supply chain performance benefits (de Jong et al. 2017). It is important to analyze *Costs* incurred in using transportation routes (see, land, or air routes), since they have an important impact on both raw material and product transportation (Liu et al. 2018a). Likewise, IT *Costs* are another important aspects to be kept in mind. IT services such as the Internet allow for real-time satellite tracking (Grzybowska and Kovács 2017; Musa et al. 2014) and thus increase supply chain visibility (Silva et al. 2017) and agility (Brusset 2016). Following this discussion, the second research hypothesis of model 2 can be proposed as follows:

H_2. In the manufacturing industry, *Regional Costs* have a positive direct effect on supply chain *Transportation* benefits.

Undoubtedly, in the manufacturing industry, *Regional Costs* have an impact on supply chain *Financial Performance*. Experts claim that fully integrated supply chain systems, which use multiple technologies and save *Costs*, directly impact corporate performance (Arani and Torabi 2018). Managers must take advantage of all the *Cost* minimization opportunities that a region has to offer without forgetting to make the necessary investments on human resources (Hong et al. 2018). Finally, *Regional Costs* minimization does not merely involve *Transportation*; companies need to rely on those manufacturing practices that allow them to achieve an appropriate *Financial Performance* (Zhao et al. 2015). These strategies are linked to a lean manufacturing approach (Fullerton et al. 2014).

Some studies report the role of supply chain costs in corporate performance and discuss those adjustments that must be performed to the systems (Wagner et al. 2012),. Managers and supply chain administrators must look for supply chain simplicity at all times in order to reduce workload and remove unnecessary activities that add unnecessary complexity to the system (Lu and Shang 2017). Nevertheless, measuring *Financial Performance* must not be limited to measuring economic aspects, but also social and environmental elements (Mani et al. 2018). In order to explore the relationship between *Regional Costs* and supply chain *Financial Performance*, the fourth research hypothesis states as follows:

H_3. In the manufacturing industry, *Regional Costs* have a positive direct effect on supply chain *Financial Performance.*

This research refers to *Proximity* as synonyms for supplier and customer proximity (outside of the company), which in turn implies that *Proximity* has an effect on *Transformation* benefits. Suppliers that are physically located far away from companies represent higher costs, whereas those physically close will imply fewer costs (Shou et al. 2017). In fact, supplier proximity is a strategic factor. Some companies even promote the development of their own local suppliers to minimize transportation *Costs* (Glock et al. 2017; Sunil Kumar and Routroy 2017). Likewise, organizations seek to remain physically close to their customers as a way to improve their relationship and minimize costs incurred in product or service distribution and delivery (Gligor et al. 2015b; Kim and Chai 2017). In this sense, to explore the relationship between *Proximity* aspects associated with suppliers, demand and support of services and *Transportation* benefits, the following research hypothesis can be proposed:

H_4. In the manufacturing industry, market *Proximity* has a positive direct effect on supply chain *Transportation* benefits.

Supplier and customer proximity are said to have an impact on *Financial Performance*. Some studies have managed to explore the effects of the proximity of service providers on corporate *Financial Performance* (Yonge 2003), whereas some others have sought to determine how raw material and product distribution routes affect both corporate *Financial Performance* and social image (Villanueva-Ponce et al. 2015). In this sense, Shi et al. (2017) found that in the Chinese manufacturing industry, distribution routes and distances play a crucial role not only in supplier evaluation and selection, but also in supplier performance. In order to minimize *Transportation* cost problems, especially when dealing with foreign customers and suppliers, supply chain ICTs must be fully integrated (Jean et al. 2010). This would provide greater *Transportation* visibility and would thus streamline decision making, thereby improving *Financial Performance* (Um 2017). Following this discussion, the fifth research hypothesis of model B can be proposed as follows:

H_5. In the manufacturing industry, the market, materials, suppliers, customers, etc. *Proximity* has a positive direct effect on supply chain *Financial Performance*.

Transportation benefits gained before or after the production process minimize overall production *Costs* and thus contribute to appropriate *Financial Performance* in supply chain systems. Some works have managed to report how the flow of raw materials and products impacts on the economic performance of companies (Pfohl and Gomm 2009); however, companies rarely depend on their single transportation means; they rather use third parties to outsource elements of their distribution and fulfillment services. Undoubtedly, third-party logistics (3PL) have both financial and environmental effects (Choi and Hwang 2015), yet they are also a source of relieve for manufacturers. In this sense, *Transportation* benefits must always be analyzed when relying on 3PL to make sure they represent true advantages in terms of costs (Selviaridis et al. 2008; Yeung 2006). Finally, researchers also recommend designing *Transportation* plans and associating them with the existing corporate strategies in order to compare and contrast corporate performance before and after the implementation of such plans (Steinrücke and Albrecht 2017). This strategy might be particularly effective when dealing with foreign suppliers and customers, which is a characteristic of the Mexican manufacturing industry (Avelar-Sosa et al. 2015).

To explore the relationship between *Transportation* benefits and supply chain *Financial Performance*, the last research hypothesis for model B can read as follows:

H_6. In the manufacturing industry, *Transportation* benefits have a positive direct effect on supply chain *Financial Performance*.

13.1.2.2 Latent Variable Validation of Complex Model B

Even though some of the latent variables included in this model were previously used, and therefore tested, the results of the validation tests are again provided in this chapter by means of Table 13.5. As mentioned in previous sections and chapters, the latent variable validation tests were performed according to the methodology chapter. Following the results summarized in the table, it is possible to conclude the following:

- The dependent latent variables have enough parametric and nonparametric predictive validity, since the values of R^2, adjusted R^2, and Q^2 are appropriate.

Table 13.5 Latent variable validation complex Model B: *Regional Factors—Benefits*

Coefficients	Regional costs	Proximity	Transportation	Financial performance
R-Squared (R^2)		0.039	0.097	0.173
Adjusted *R*-Squared		0.034	0.089	0.162
Composite reliability	0.838	0.807	0.848	0.837
Cronbach's alpha index (CAI)	0.739	0.640	0.730	0.705
Average variance extracted (AVE)	0.568	0.584	0.652	0.634
Full collinearity VIF	1.077	1.079	1.145	1.116
Q-Squared (Q^2)		0.041	0.098	0.170

- All the latent variables have enough internal validity, since both the composite reliability index and the CAI have values higher than 0.7.
- All the latent variables have sufficient convergent validity, as indicated by AVE, which is higher than 0.5 in all cases. However, it is important to mention that item "Labor costs make your operations competitive" was removed from the analysis.
- Finally, none of the latent variables have internal collinearity problems, since VIF values are lower than 3.3.

13.1.2.3 Results of Complex Model B: *Regional Factors—Benefits*

The model depicted in Fig. 13.3 was tested according to the methodology chapter. The results obtained from the evaluation process are introduced in a new figure; that is Fig. 13.4. As in previous models, the research hypotheses represent direct relationships between latent variables. Each relationship has a β value and a P value. The former is a measure of dependency, whereas the latter indicates the statistical significance of the relationship and thus the effect. Relationships with a P value lower than 0.5 are statistically significant at a 95% confidence level. Finally, each dependent latent variable is associated with an R^2 value as a measure of explained variance.

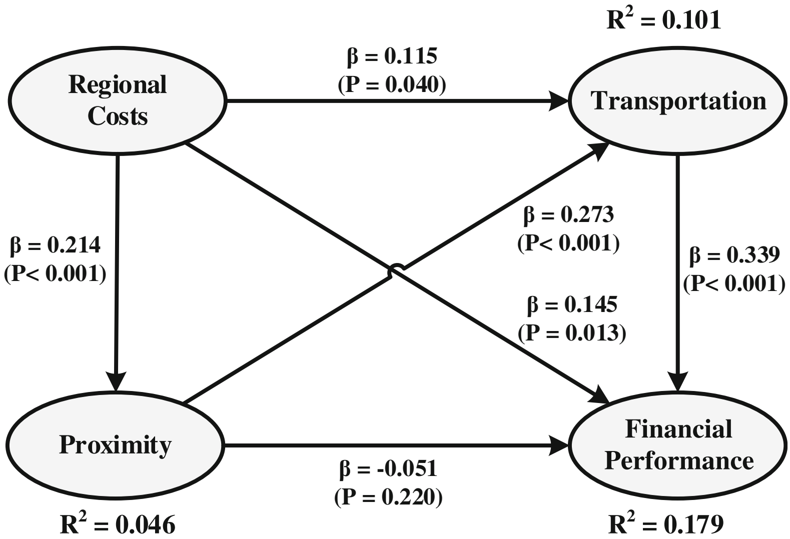

Fig. 13.4 Complex Model B evaluated: *Regional Factors—Benefits*

According to Fig. 13.4, it possible to conclude the following:

- Five relationships, and hence research hypotheses, are statistically significant. However, the P value the other relationship is higher than 0.05. Therefore, the relationship is not statistically significant.
- The model has enough predictive validity, since the values of R^2 are all higher than 0.02.

Once the hypotheses have been tested, the model must be tested as whole construct.

13.1.2.4 Model Fit and Quality Indices in Complex Model B: *Regional Factors—Benefits*

Once latent variables and research hypotheses have been tested, SEM models must be assessed as a whole to determine their quality. In this sense, ten model fit and quality indices were estimated to assess Model B. For further information on these indices as well as on the assessment procedure, please refer to the methodology chapter. The evaluation results for this model are listed below:

- Average Path Coefficient (APC) = 0.190, $P < 0.001$
- Average R-Squared (R^2) (ARS) = 0.101, $P = 0.031$
- Average Adjusted R-Squared (AARS) = 0.093, $P = 0.039$
- Average block VIF (AVIF) = 1.118, acceptable if ≤ 5, ideally ≤ 3.3
- Average Full collinearity VIF (AFVIF) = 1.114, acceptable if ≤ 5, ideally ≤ 3.3
- Tenenhaus GoF (GoF) = 0.28, small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36
- Simpson's Paradox Ratio (SPR) = 0.833, acceptable if ≥ 0.7, ideally = 1
- R-Squared Contribution Ratio (RSCR) = 0.966, acceptable if ≥ 0.9, ideally = 1
- Statistical Suppression Ratio (SSR) = 1.000, acceptable if ≥ 0.7
- Nonlinear Bivariate Causality Direction Ratio (NLBCDR) = 0.917, acceptable if ≥ 0.7

According to these results, the model has overall acceptable explanatory power, since APC has a P value lower than 0.5. Similarly, both ARS and AARS have P values lower than 0.5, which indicates that the model has parametric and non-parametric predictive validity. Moreover, AVIF and AFVIF values (both lower than 3.3) demonstrate that the model is free from internal collinearity problems, whereas the Tenenhaus GoF is higher than 2.5 and thus indicates a good model fit. Finally, the reaming indices confirm that the hypotheses were formulated in the right sense and direction. The model can now be successfully interpreted. As a remainder, one item from *Costs* was removed from the analysis to improve the reliability of the latent variable.

13.1.2.5 Direct Effects

Direct effects support the statistical validation process of the hypotheses proposed in Fig. 13.3. The conclusions as regards these hypotheses are depicted in Fig. 13.4 and can be interpreted as follows:

H_1. In the manufacturing industry, there is enough statistical evidence to claim that *regional Costs* have a positive direct effect on market *Proximity*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.214 standard deviations.
H_2. In the manufacturing industry, there is enough statistical evidence to claim that *Regional Costs* have a positive direct effect on *Transportation* benefits, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.115 standard deviations.
H_3. In the manufacturing industry, there is enough statistical evidence to claim that *regional Costs* have a positive direct effect on supply chain *Financial Performance*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.145 standard deviations.
H_4. In the manufacturing industry, there is enough statistical evidence to claim that *Operational Aspects* have a positive direct effect on *Transportation* benefits, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.273 standard deviations.
H_5. There is not enough statistical evidence to claim that market, materials, suppliers, clients, market *Proximity* have a positive direct effect on supply chain *Financial Performance*. According to the results, the P value is higher than 0.5. Moreover, the β value is negative.
H_6. In the manufacturing industry, there is enough statistical evidence to claim that market *Proximity* has a positive direct effect on supply chain *Financial Performance*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.339 standard deviations.

13.1.2.6 Effect Sizes

Dependent latent variables are usually associated with an R^2 value that indicates their percentage of explained variance. When two or more independent latent variables explain the variance of a dependent latent variable, the resulting R^2 value must be decomposed to determine the effect sizes; that is the portion of variance that each independent latent variable can explain. For this second model of regional factors and benefits, Table 13.6 reports the effect sizes for each relationship.

As depicted in Fig. 13.4, *Regional Costs* and market *Proximity* together explain 10.1% of the variability of *Transportation* benefits; however, according to Table 13.6, market *Proximity* is the most important, since it explains 8.1% of that estimated variance. Similarly, Fig. 13.4 indicates that the variance of *Financial Performance* is 17.9% explained by latent variables *Regional Costs, Proximity*, and

Table 13.6 Effect sizes for complex Model B

To	From			R^2
	Regional costs	Proximity	Transportation	
Proximity	0.046			0.046
Transportation	0.020	0.081		0.101
Financial performance	0.035	0.011	0.133	0.179

Transportation benefits. Nevertheless, Table 13.6 reveals that the latter is responsible for the highest percentage. Such results imply that supply chain performance mostly depends on those *Transportation* benefits that companies obtain.

13.1.2.7 Sum of Indirect Effects

In structural equation modeling, two latent variables can be indirectly related. Indirect relationships, and thus indirect effects, occur through mediator variables and can be tracked by following two or more model paths. The indirect effects found in Model B are summarized in Table 13.7.

According to the results, the following conclusions can be proposed:

- Two out of the three indirect effects are not statistically significant at a 95% confidence level since their corresponding *P* values are higher than 0.5. In other words, the indirect relationships between *Regional Costs* and *Transportation* benefits, and between *Regional Costs* and *Financial Performance*, are not significant. However, surprisingly, the direct relationships are significant (see subsection 13.4.2.2, hypotheses H_2 and H_3). Such results suggest that the influence of market *Proximity* on these relationships is not favorable.
- The indirect relationship between market *Proximity* and *Financial Performance,* occurring through *Transportation* benefits, is statistically significant and so it the effect. Interestingly, the direct relationship between these latent variables is not statistically significant (see subsection 13.4.2.2, hypotheses H_5), which demonstrates once again the importance of *Transportation* benefits in supply chain *Financial Performance.* Therefore, managers must focus their efforts on gaining the necessary *Transportation* benefits to guarantee a good *Financial Performance*.

Table 13.7 Sum of indirect effects in complex Model B

To	From	
	Regional costs	Proximity
Transportation	0.059 (*P* = 0.105) ES = 0.047	
Financial performance	0.048 (*P* = 0.235) ES = 0.066	0.093 (*P* = 0.023) ES = 0.046

13.1.2.8 Total Effects

Total effects in a relationship are the sum of both direct and indirect effects. They are an important step in SEM analyses because they allow determining whether a given relationship is statistically significant in spite of having either direct or indirect effects that are not statistically significant. Table 13.8 reports the total effects found for the relationships between latent variables in Model B. As in previous sections, these effects must have *P* values lower than 0.5 in order to be statistically significant at a 95% confidence level.

According to the results summarized in the abovementioned table, the following conclusions can be proposed:

- Five total effects are statistically significant, and one is not. The relationship between market *Proximity* and *Financial Performance* does not have significant total effects, yet this was previously detected in the direct effects estimation step.
- Indirect effects played a crucial role in the total significance in two relationships. On the one hand, the relationship between *Regional Costs* and *Transportation* benefits has significant total effects thanks to the presence of market *Proximity*. Likewise, the relationship between regional *Costs* and *Financial Performance* has significant total effects due to the influence of *Transportation* benefits.

13.1.2.9 Conclusions for Complex Model B: *Regional Factors—Benefits*

The analysis and evaluation of Model B allow us to propose the following final conclusions:

- Despite being statistically validated, the model has relatively low explanatory power, as indicated by the R^2 coefficients. Such results demonstrate that more latent variables are necessary to increase the model's explanatory capabilities.
- Latent variable market *Proximity*, which can be associated with supplier and market proximity and regional competition, was expected to have significant direct effects on regional *Costs*. Nevertheless, the relationship is only significant

Table 13.8 Total effects in complex Model B

To	From		
	Regional costs	Proximity	Transportation
Proximity	0.214 ($P < 0.001$) ES = 0.046		
Transportation	0.173 ($P = 0.004$) ES = 0.030	0.273 ($P < 0.001$) ES = 0.081	
Financial performance	0.193 ($P = 0.002$) ES = 0.046	0.042 ($P = 0.265$) ES = 0.009	0.339 ($P < 0.001$) ES = 0.133

if it is indirect, thanks to *Transportation* benefits. In other words, it is important that companies focus their efforts on designing and relying on appropriate and effective *Transportation* networks and systems, including satellite tracking and geolocation, since they play a crucial role in *Financial Performance*. This makes sense from a point of view in which the proximity allows greater competitiveness of enterprises through results agile in their supply chains, which certainly involves aspects of transport infrastructure. In other words, the economic benefits are a consequence of those obtained in the transport.
- On the other hand, the costs associated with the availability of land, labor, telecommunications, or other aspects of infrastructure services certainly affect the financial results achieved by the companies. This means that so the company displayed long-term returns you should take into account the cost not only in relation to the product or manufacturing but also consider the costs associated with the operation of the same. Idea that is supported by the work of Avelar-Sosa et al. (2014), which says that costs of logistics services affect deliveries of products and service customer and therefore the economic benefits that could arise because of this.

13.1.3 Complex Model C: Regional Factors—Benefits

Here is proposed a third model to evaluate the effects of regional factors on supply chain performance benefits. Namely, the model associates one regional element variable: *Workforce*, with three supply chain performance benefits—*Flexibility, Agility*, and *Customer Service*.

This model integrates one regional impact factor and three supply chain performance benefits. The latent variables are listed below:

Regional impact factors:

- *Workforce* (three observed variables or items)

Supply chain performance benefits:

- *Flexibility* (six observed variables or items)
- *Agility* (seven observed variables or items)
- *Customer Service* (three observed variables or items).

For further information of this observed variable, please refer to the appendix section and consult the attached sample survey.

The four latent variables in the model are associated with six research hypotheses. As in previous models, these hypotheses must be statistically tested to validate the relationships for which they stand. The model assumes that regional *Workforce* can provide the necessary supply chain *Flexibility* and *Agility* to guarantee quality *Customer Service.* The six research hypotheses used to support this assumption are depicted in Fig. 13.5 and will be discussed in the following paragraphs

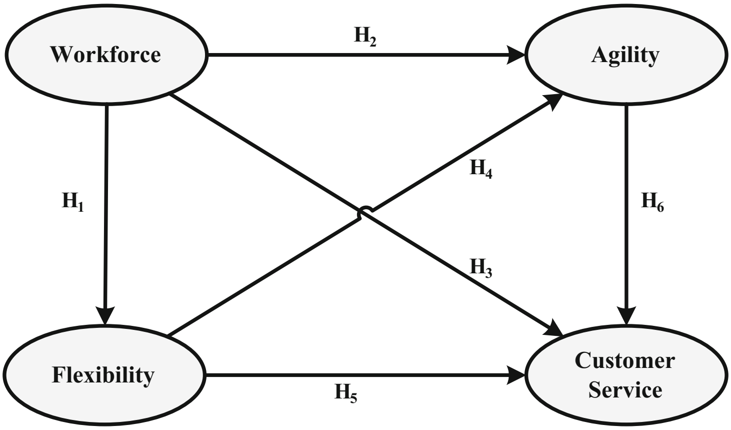

Fig. 13.5 Complex Model C proposed: *Regional Factors—Benefits*

13.1.3.1 Hypotheses Formulation: Complex Model C

This subsection discusses the six validated relationships between regional infrastructure and supply chain performance benefits in the manufacturing industry. *Workforce* is one of the most important regional elements for supply chain success. Consequently, its availability and level of expertise are often evaluated. The impact of *Workforce* on corporate performance reflects on the production process and on how well supply chain systems operate as a constituent (Qin et al. 2015). Companies with a highly qualified workforce are able to make orderly and timely deliveries and succeed in responding to sudden market changes. In her work, Barad (2012) developed a supply chain *Flexibility* assessment model and found *Workforce* as one of the most significant impact variables.

Additionally, Gong (2008) evaluated *Flexibility* as a wealth generator through an economic model that identifies employee abilities and skills and sources of *Flexibility*. From a similar perspective, Gosling et al. (2017) claimed that engineers and supply chain leaders play a key role in supply chain *Flexibility* performance, not only production lines operators. Finally, according to a research work conducted by Lim et al. (2017), knowledge management processes and supply chain performance are significantly related. Following this discussion, the first research hypothesis in Model C is proposed as follows:
H_1. In the manufacturing industry, regional *Workforce* has a positive direct effect on supply chain *Flexibility*.

Not only *Workforce* is a source of *Flexibility*, but also of *Agility*. *Flexibility* refers to the different forms in which businesses can perform a given activity, whereas *Agility* involves the speed at which such activities are performed. In this sense, authors Samdantsoodol et al. (2017) claim that supply chain virtualization as a future trend will increase business *Agility* but demands a highly qualified

Workforce with vast knowledge on ICTs. Similarly, Um et al. (2017) argue that production *Agility* largely depends on the business's organizational structure and innovation capabilities, which are possible thanks to human resources. Since the literature on business and supply chain *Agility* is vast, readers are advised to consult Yusuf et al. (2004) for a more comprehensive overview of this topic. Meanwhile, the second research hypothesis for Model C states the following:

H_2. In the manufacturing industry, regional *Workforce* has a positive direct effect on supply chain *Agility*.

Employees are the most valuable element of companies. Corporate success depends on how employees perform and therefore act (Bogataj et al. 2017). According to Dossou and Nachidi (2017), sales employees are the face of companies, and thus, their training is indispensable. They must be aware of aspects such as actual delivery times in order to avoid customer problems. Similarly, vendors must not commit to delivering products at times that are not scheduled by the manufacturer and without knowing existing manufacturing constraints.

Production line operators are also indispensable. Their skills and experience allow orders to be completed on time and thus have an impact on *Customer Service* (Tanai and Guiffrida 2015). Contrary to what is commonly believed, a study conducted by (Ali et al. 2018) demonstrates that operators are as important as vendors in terms of corporate image sustainability. Moreover, even though it is often assumed that low prices by themselves, without considering product quality, can guarantee *Customer Service,* it has been proved that sophisticated and well-informed customers want to more about the product they are purchasing, not only their price (Zhou et al. 2018). In this sense, the fourth research hypothesis for Model C can be formulated as follows:

H_3. In the manufacturing industry, regional *Workforce* has a positive direct effect on *Customer Service*.

Companies that are flexible are more agile (Wadhwa et al. 2008), since they rely on multiple methods to perform the same operation. In a study conducted by Yusuf et al. (2004), *Flexibility* and *Agility* aspects are explored with respect to economic income and are proved to have significant effects. Additionally, Sreedevi and Saranga (2017) claim that *Flexibility* is a source of *Agility* but also mitigates supply chain risks. Consequently, the authors advise companies to prioritize and invest in *Workforce* training as their major source of *Flexibility.* In a different research work, the authors highlight the importance of implementing changeover methodologies, such as SMED, to prevent production delays, increase machine availability, and decrease production cycle times (Subramaniya 2017). Likewise, to increase business *Agility*, ICTs must be adequately implemented (Setia et al. 2008), and lean manufacturing practices must be adopted to reduce bottlenecks (Kazemian and Aref 2016). Following this discussion, the third research hypothesis can be proposed below:

H_4. In the manufacturing industry, supply chain *Flexibility* has a positive direct effect on supply chain *Agility*.

In order to face unexpected demand changes (e.g., when customers modify product requirement preferences after placing the order), manufacturers must be able to rapidly adjust their production processes, thereby demonstrating production *Flexibility*. However, sometimes this *Flexibility* might demand changes in delivery times that should be accepted by customers (He and Chen 2018). This phenomenon has been studied from multiple perspectives. For instance, Xu et al. (2017) explored the effects of *Flexibility* in e-service offerings over customer demand. The authors examined the operational adjustments that companies have to perform in order to meet unexpected demand requirement changes and deliver the resulting orders correctly and on time. On the other hand, Farooq et al. (2018) studied the impact of *Flexibility* on quality standards and *Customer Service* in the airline industry.

In supply chain systems, the impact of unexpected demand changes on *Customer Service* has been analyzed as a risk factor that can be mitigated through *Flexibility* (Chatzikontidou et al. 2017). Some authors claim that flexible companies are good for customers, yet the best alternative is to settle a contract between buyers and vendors that explicitly states minimum deadlines and quantities (Chen et al. 2017). In other words, the specific constraints (i.e., production capabilities or quality) of each actor must be part of a formal agreement (Liu et al. 2018b). Finally, companies with multifunctional workers are more prepared to tackle employee absenteeism and potential delivery delays. Nevertheless, organizations must not underestimate the importance of those methodologies that support the production process. For instance, SMED is an effective tool for increasing product variety without compromising production timing and meeting scheduled production orders (Brito et al. 2017). Following this discussion, the fifth research hypothesis for Model C is proposed below:

H_5. In the manufacturing industry, supply chain *Flexibility* has a positive direct effect on *Customer Service*.

Rapid deliveries are an indicator of corporate *Agility* in supply chain systems. Since *Agility* is a valued attribute by customers (Senapathi and Drury-Grogan 2017), several studies have sought to understand its relationship with *Customer Service*. For instance, the literature reports the effects of *Agility* on corporate performance, whose ultimate component is customer satisfaction in terms of delivery time compliance and product customization (Um 2017). Similarly, Yang (2014) explored *Agility* as a strategy for surviving in globalized markets, whereas Setia et al. (2008) recommend implementing information technologies to streamline *Customer Service* and improve supply chain interaction and visibility. Finally, in their research, Gligor et al. (2015a) found that *Customer Service* and satisfaction are the two major corporate *Agility* benefits. In this sense, the sixth and last research hypothesis for Model C can be proposed as follows a Fig. 13.5.

H_6. In the manufacturing industry, supply chain *Agility* has a positive direct effect on *Customer Service*.

13.1.3.2 Latent Variable Validation of Complex Model C

Even though some of the latent variables included in this model were previously used, and therefore tested, the results of the validation tests are again provided in this subsection using Table 13.9. As mentioned in previous sections and chapters, the latent variable validation tests were performed according to the methodology chapter.

With the results summarized in Table 13.9, it is possible to conclude the following:

- All the dependent latent variables have appropriate predictive validity from parametric and nonparametric perspectives, since the values of coefficients R^2, adjusted R^2, and Q^2 are all higher than 0.02.
- All the latent variables have enough internal and composite reliability. Both the composite reliability index and the CAI have values higher than 0.7, the minimum acceptable value.
- According to the values of AVE (all higher than 0.5), the four latent variables have enough convergent validity.
- No internal collinearity problems exist in the latent variables. The values of VIF are all lower than 3.3.

13.1.3.3 Results of Complex Model C: *Regional Factors—Benefits*

After the latent variables were individually validated, the model was run as described in the methodology chapter. Figure 13.6 depicts model after being run. Every hypothesized relationship has a β value and P value.

The former is a measure of dependency, whereas the latter indicates the statistical significance of the effects. Relationships with a P value lower than 0.5 are statistically significant at a 95% confidence level. Additionally, each dependent latent variable is associated with an R^2 value as a measure of explained variance. According to Fig. 13.6, it is possible to propose the following assumptions:

Table 13.9 Latent variable validation complex Model C: *Regional Factors—Benefits*

Coefficients	Customer service	Agility	Workforce	Flexibility
R-Squared (R^2)	0.478	0.352		0.125
Adjusted R-Squared	0.470	0.346		0.121
Composite reliability	0.857	0.876	0.885	0.854
Cronbach's alpha index (CAI)	0.750	0.833	0.805	0.795
Average variance extracted (AVE)	0.667	0.516	0.720	0.505
Full collinearity VIF	1.845	2.167	1.129	1.692
Q-Squared (Q^2)	0.480	0.396		0.124

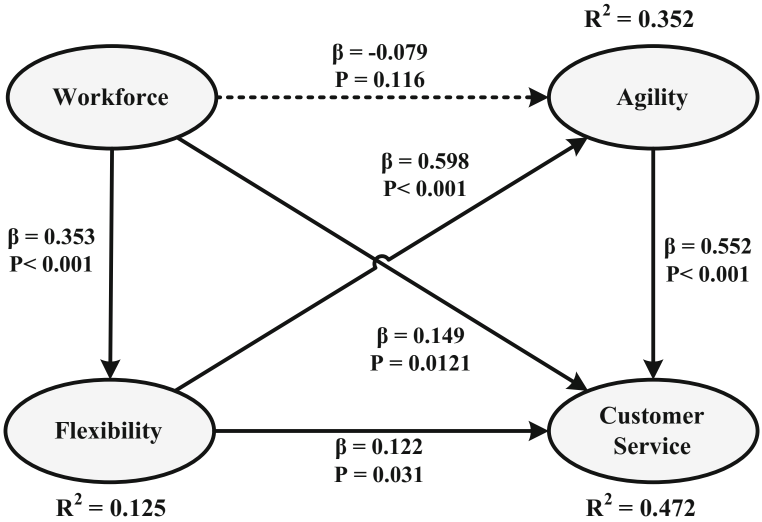

Fig. 13.6 Complex Model C evaluated: *Regional Factors—Benefits*

- Only five hypotheses and thus direct relationships between latent variables are statistically significant. The remaining not significant hypothesis is illustrated as a dotted arrow.
- All the dependent latent variables have R^2 values higher than 0.02. Therefore, the model has enough overall predictive validity.
- The model can now be tested as a unified construct.

13.1.3.4 Model Fit and Quality Indices in Complex Model C: *Regional Factors—Benefits*

According to our research methodology, ten model fit and quality indices were estimated as follows:

- Average Path Coefficient (APC) = 0.309, $P < 0.001$
- Average R-Squared (R^2) (ARS) = 0.318, $P < 0.001$
- Average Adjusted R-Squared (AARS) = 0.312, $P < 0.001$
- Average block VIF (AVIF) = 1.330, acceptable if ≤ 5, ideally ≤ 3.3
- Average Full collinearity VIF (AFVIF) = 1.708, acceptable if ≤ 5, ideally ≤ 3.3
- Tenenhaus GoF (GoF) = 0.437, small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36
- Simpson's Paradox Ratio (SPR) = 0.833, acceptable if ≥ 0.7, ideally = 1
- R-Squared Contribution Ratio (RSCR) = 0.977, acceptable if ≥ 0.9, ideally = 1
- Statistical Suppression Ratio (SSR) = 1.000, acceptable if ≥ 0.7
- Nonlinear Bivariate Causality Direction Ratio (NLBCDR) = 1.000, acceptable if ≥ 0.7

The model test results indicate that, overall, all the β values are statistically significant. Similarly, since both ARS and AARS have P values lower than 0.5, we can conclude that the model has enough predictive validity. As for VIF and AFVIF values (both lower than 3.3), they demonstrate that the construct is free from collinearity problems.Meanwhile, the Tenenhaus GoF suggests a good model fit, whereas the remaining indices confirm that the hypotheses were proposed in the correct sense and direction. This because the GoF index to the model es 0.437, exceeding the minimum allowable value.

13.1.3.5 Directs Effects

Once the latent variables have been individually tested, and the model was evaluated as well, the results depicted in Fig. 13.6 can be interpreted.

H_1. In the manufacturing industry, there is enough statistical evidence to claim that regional *Workforce* has a positive direct effect on supply chain *Flexibility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.353 standard deviations.
H_2. There is not enough statistical evidence to claim that regional *Workforce* has a positive direct effect on supply chain *Agility*, since the P value associated with this relationship is higher than 0.05 (i.e., $P = 0.116$).
H_3. In the manufacturing industry, there is enough statistical evidence to claim that regional *Workforce* has a positive direct effect on *Customer Service*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.149 standard deviations.
H_4. In the manufacturing industry, there is enough statistical evidence to claim that supply chain *Flexibility* has a positive direct effect on supply chain *Agility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.214 standard deviations.
H_5. In the manufacturing industry, there is enough statistical evidence to claim that supply chain *Flexibility* has a positive direct effect on *Customer Service*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.122 standard deviations.
H_6. In the manufacturing industry, there is enough statistical evidence to claim that supply chain *Agility* has a positive direct effect on *Customer Service*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.552 standard deviations.

13.1.3.6 Effect Sizes

As illustrated in Figs. 13.5 and 13.6, the variance of dependent latent variables can be explained by one or multiple independent latent variables. To determine to what extent each independent latent variable explains the variability of a dependent variable in Model C, Table 13.10 reports the effect sizes found. According to Fig. 13.6, together three latent variables explain 47.8% of the variance of *Customer Service*. However, the most important is *Agility*, as it explains 36.6% by itself (i.e., ES = 0.366).

Such results demonstrate that customers always seek agile orders and deliveries. On the other hand, the low impact of both *Workforce* and *Flexibility* might be due to the fact that both factors are internal and can rarely be visible to customers. Finally, notice that *Workforce* has a negative impact on *Agility*, yet as a reminder, the direct relationship is not statistically significant. Instead, it is the indirect relationship that is significant. This will be discussed in the following section.

13.1.3.7 Sum of Indirect Effects

Latent variables can be indirectly related thanks to the presence of mediator variables. These relationships are composed of two or model segments. Table 13.11 reports the effects estimated in the indirect relationships. As in direct effects, indirect effects have a β value as a measure of dependency and a P value as an indicator of statistical significance.

Table 13.10 Effect sizes in complex Model C

To	From			R^2
	Agility	Workforce	Flexibility	
Customer service	0.366	0.050	0.062	0.478
Agility		−0.023	0.375	0.352
Flexibility		0.125		0.125

Table 13.11 Sum of indirect effects in complex Model C

To	From	
	Workforce	Flexibility
Customer service	0.117 (P = 0.038) ES = 0.039	0.331 (P < 0.001) ES = 0.167
Agility	0.211 (P < 0.001) ES = 0.061	

According to the results, it is possible to propose the following conclusions:

- Three indirect relationships were found, and their corresponding indirect effects are all statistically significant at a 95% confidence level.
- The direct effect between *Workforce* and *Agility* was not statistically significant, yet the indirect effect is significant. The indirect relationship occurs through latent variable *Flexibility*, thereby suggesting that human resources (*Workforce*) need to ensure supply chain *Flexibility* in order to gain supply chain *Agility*. That is to say, *Agility* is a consequence of *Flexibility*. Therefore, managers and decision makers must prioritize *Flexibility* goals among their *Workforce*.
- *Flexibility* also has an indirect effect on *Customer Service* through *Agility*. This is the largest of the three indirect effects and explains up to 16.7% of the variance of *Customer Service*. Moreover, it is larger than the direct effect found for H_5. This demonstrates the importance of *Agility* practices in *Customer Service*. The indirect effect is almost three times larger than the indirect effect.

13.1.3.8 Total Effects

Estimating total effects in SEM is important, since they determine whether a given relationship is statistically significant in spite of having either direct or indirect effects that are not statistically significant. Table 13.12 reports the total effects found for the relationships between the latent variables in Model C. As in previous sections, *P* values lower than 0.5 are an indicator of statistically significant effects.

According to the results summarized in table, the following conclusions can be proposed with respect to the total effects in the relationships:

- All the total effects are statistically significant, including those calculated in the relationship whose direct effects were not significant.
- The largest total effects are direct effects. They occur in the relationship between *Flexibility* and *Agility*. This result confirms the importance of being a flexible business in order to become agile. Investments must be made in those alternatives and methods that allow customer needs to be met rapidly.

Table 13.12 Total effects in complex Model C

To	From		
	Agility	Workforce	Flexibility
Costumer service	0.552 ($P < 0.001$) ES = 0.366	0.265 ($P < 0.001$) ES = 0.089	0.453 ($P < 0.001$) ES = 0.228
Agility		0.133 ($P = 0.021$) ES = 0.038	0.598 ($P < 0.001$) ES = 0.375
Flexibility		0.353 ($P < 0.001$) ES = 0.125	

- The relationship between *Agility* and *Customer Service* has prominent results. The total effects report $\beta = 0.552$ and thus indicate that the level of customer appreciation on agile service and support is high.

13.1.3.9 Conclusions for Complex Model C: *Regional Factors—Benefits*

Perhaps the most important steps in structural equation modeling are the interpretation of the results and the discussion of the implications. Specifically for this third model that associates one regional impact factor with three supply chain performance benefits, the following conclusions can be proposed:

- *Workforce* alone does not generate supply chain *Agility*. We found that the direct effect in this relationship was not statistically significant, yet the indirect effect given through supply chain *Flexibility* is significant. Such results imply that human resources (i.e., *Workforce*) must have the necessary skills and abilities to meet customer needs rapidly and in many ways. This is because in the model labor presents contribution indirectly in the *Agility* of the chain through the *Flexibility, w*hich makes sense, since companies problems that continually occur in the system are managed from an operational point of view, and when problems are avoided or correcting errors from the source will improve response to changes times that it may arise in contracts or customers' requirements.
- Supply chain *Flexibility* alone does not have a strong impact on *Customer Service,* since the direct effect was low. Instead, companies must convert *Flexibility* into *Agility* in order to provide customers with benefits.
- To summarize, this model found that both *Workforce* and *Flexibility* can only have an impact on *Customer Service* thanks to supply chain *Agility*, which refers to the speed at which customer needs can be correctly met.

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Chapter 14
The Role of Manufacturing Practices in Supply Chain Performance

14.1 Latent Variables

This chapter explores the relationships between four major manufacturing practices and eight supply chain performance benefits. Their corresponding latent variables can be listed below:

Manufacturing practices:

- *Total Quality Management*
- *Just in Time*
- *Maintenance*
- *Advanced Manufacturing Technology*

Supply chain performance benefits:

- *Delivery Times*
- *Quality*
- *Flexibility*
- *Customer Service*
- *Agility*
- *Financial Performance*
- *Inventory*
- *Transportation*

The following section proposes a series of models to relate these variables. First, two simple models are proposed to exemplify how each manufacturing practice variable can be associated with each benefit variable. Then, we summarize the remaining relationships that cannot be thoroughly developed due to content constraints. Finally, the last model explores the interrelations among the four manufacturing practices.

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Management and Industrial Engineering,
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14.2 Simple Models: Manufacturing Practices–Supply Chain Performance (Benefits)

14.2.1 Simple Model A: Total Quality Management–Quality

This model seeks to relate two latent variables: one manufacturing practice with one supply chain performance benefit. Namely, the model explores the relationship between *Total Quality Management* (TQM, independent latent variable) and *Quality* (dependent latent variable). The goal is to demonstrate that TQM practices have an impact on production and product quality. Figure 14.1 depicts this hypothesis, which must be tested statistically.

14.2.1.1 Hypotheses Formulation: Simple Model A

Quality benefits are not obtained overnight; they are rather the result of careful planning along the supply chain (Siddiqui et al. 2012). In their work, Siddiqui et al. (2009) conducted a literature review and reported the impact of good TQM practices on flexible production and customer demand compliance. On the other hand, Zeng et al. (2013) developed a structural equation model to measure the impact of human-related aspects of TQM on corporate performance and customer satisfaction, the latter being a *Quality* measure. Similarly, Hong et al. (2018) researched the role of TQM planning in corporate dynamism and highlighted that TQM reflects on the extent to which companies are able to comply with required product technical specifications.

TQM practices do not only have an impact on the manufacturing industry, as its benefits have also been guaranteed in other sectors. For instance, authors Besik and Nagurney (2017) present an appealing study among agricultural products in which TQM implementation is assessed. Furthermore, Kwon et al. (2016) report a study in a healthcare supply chain system and found that quality management practices improve both *Quality* and financial performance. Following this discussion, the research hypothesis for model A can be proposed below:

H_1. In the manufacturing industry, *Total Quality Management* implementation has a positive direct effect on product *Quality*.

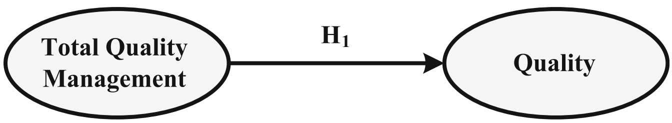

Fig. 14.1 Simple Model A proposed: *Total Quality Management–Quality*

14.2.1.2 Latent Variable Validation of Simple Model A

The model illustrated in Fig. 14.1 is run according to the methodology chapter. The run model is introduced in Fig. 14.2. Notice that the research hypothesis is associated with a β value and a P value. The former is a measure of dependency, whereas the latter is an indicator of statistical significance. P values lower than 0.5 imply statistically significant relationships. Similarly, dependent latent variable *Quality* includes an R^2 value as a measure of explained variance.

Table 14.1 summarizes the latent variable validation results. As discussed in the methodology chapter, seven latent variable coefficients were estimated to determine whether each latent variable had enough validity and could thus remain in the model.

According to the information reported in the table, it is possible to propose the following conclusions:

- The dependent latent variable has enough parametric and nonparametric validity, since the values of R^2 and adjusted R^2 are higher than 0.02. Moreover, Q^2 is higher than 0 and similar to its corresponding R^2 value.
- The two latent variables have enough internal validity, since both the composite reliability index and the CAI have values higher than 0.7.
- There is enough convergent validity in the two latent variables, since AVE values are higher than 0.5.
- The two latent variables are free from internal collinearity problems since VIF values are lower than 3.3.

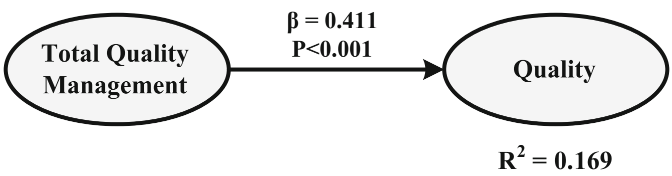

Fig. 14.2 Simple Model A evaluated: *Total Quality Management–Quality*

Table 14.1 Latent variable validation simple Model A: *Total Quality Management–Quality*

Coefficient	*Total Quality Management*	*Quality*
R-squared (R^2)		0.169
Adjusted R^2		0.165
Composite reliability	0.911	0.835
Cronbach's alpha index (CAI)	0.854	0.705
Average variance extracted (AVE)	0.774	0.717
Full collinearity VIF	1.181	1.181
Q-Squared (Q^2)		0.172

Once the latent variables have been individually assessed, the model must be tested as a whole.

Ten model fit and quality indices are estimated to measure the quality of the model. The evaluation results are listed below:

- Average Path Coefficient (APC) = 0.411, $P < 0.001$
- Average R-Squared (R^2) (ARS) = 0.169, $P = 0.002$
- Average Adjusted R-Squared (AARS) = 0.165, $P = 0.003$
- Average Full collinearity VIF (AFVIF) = 1.181, acceptable if ≤ 5, ideally ≤ 3.3
- Tenenhaus GoF (GoF) = 0.355, small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36
- Simpson's Paradox Ratio (SPR) = 1.000, acceptable if ≥ 0.7, ideally = 1
- R-Squared Contribution Ratio (RSCR) = 1.000, acceptable if ≥ 0.9, ideally = 1
- Statistical Suppression Ratio (SSR) = 1.000, acceptable if ≥ 0.7
- Nonlinear Bivariate Causality Direction Ratio (NLBCDR) = 1.000, acceptable if ≥ 0.7

Once the latent variables were individually tested and the model was also evaluated, the model can be interpreted accordingly.

14.2.1.3 Interpretation of Simple Model A

According to the estimated latent variable coefficients and model fit and quality indices, the tested and validate research hypothesis can be interpreted as follows:

H_1. In the manufacturing industry, there is enough statistical evidence to claim that *Total Quality Management* implementation has a positive direct effect on product *Quality*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.411 standard deviations.

Such results imply that if companies constantly implement TQM practices (e.g., statistical process control, internal quality audits, six sigma), products will meet required *Quality* standards. Consequently, customer complaints will decrease. Even though this relationship might seem logical, the main contribution is this model is that it quantifies the impact of planning on the obtained results.

To contribute to our understanding of this phenomenon, the chart in Fig. 14.3 illustrates the relationship between the two latent variables by including their standardized values.

As depicted in the chart, in the *Total Quality Management* interval that ranges from −3.07 to −2.20, *Quality* decreases significantly, reaching approximately −0.78. Then, *Quality* shows an upward slope and increases as *Total Quality Management* also increments. In other words, as companies implement quality systems, production process *Quality* increases and product requirements from customers are timely and orderly met.

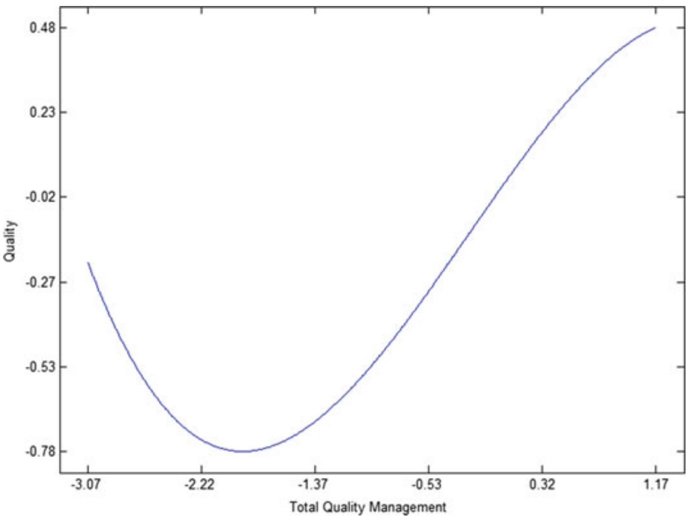

Fig. 14.3 Relationship standardized values between *Total Quality Management–Quality*

14.2.2 *Simple Model B:* Just in Time–Delivery Times

This second simple model relates another manufacturing practice with another supply chain performance benefit. The involved latent variables are *Just in Time* and *Delivery Times*. The goal is to determine the impact of JIT practices on production process and *Delivery Times*. Figure 14.4 introduces the initial model with its corresponding research hypothesis.

14.2.2.1 Hypotheses Formulation: Simple Model B

Just in time (JIT) is one of the most popular manufacturing practices (Grout and Christy 1999). The goal of a JIT production process is to meet *Delivery Times* commitments and improve inventory management. A wide range of research works report the success of JIT and praise its benefits. Authors Fandel and Trockel (2016) studied the interrelations among JIT implementation, batch sizes, and *Delivery Times*, whereas Ravi Raju et al. (1997) simulated multiple customer satisfaction environments under JIT raw material supply conditions. Meanwhile, Hazır and

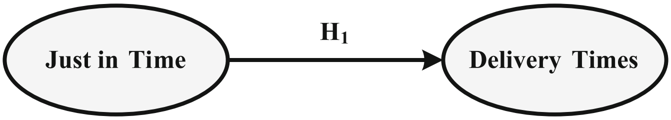

Fig. 14.4 Simple Model B proposed: *Just in Time–Delivery Times*

Kedad-Sidhoum (2014) highlighted the importance of batch size on JIT deliveries, while Kumar et al. (2004) offer a list of JIT implementation requirements that guarantee benefits in the Indian automotive industry. As for the manufacturing industry in Mexico, Montes (2014) performed a similar analysis and concluded that *Delivery Times* are one of the most important JIT benefits. In this sense, the research hypothesis for simple model B reads as follows:

H_1. In the manufacturing industry, *Just in Time* implementation has a positive direct effect on product *Delivery Times*.

14.2.2.2 Latent Variable Validation of Simple Model B

Seven latent variable coefficients were estimated as discussed in the methodology chapter in order to test the validity of the latent variables. The evaluated model is introduced in Fig. 14.5, where a β value and a P value are provided for the hypothesis. The former indicates dependency in standard deviations, whereas the latter indicates the statistical significance of the relationship and thus the direct effect. Finally, as in previous models, dependent latent variable *Delivery Times* includes and R^2 value as a measure of explained variance.

According to the latent variable coefficients reported in Table 14.2, and as depicted in Fig. 14.5, it is possible to propose the following conclusions:

- The dependent latent variable (*Delivery Times*) has enough parametric, since the values of R^2 and adjusted R^2 are higher than 0.02. Moreover, Q^2 is higher than 0

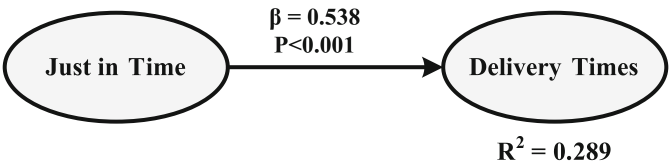

Fig. 14.5 Simple Model B evaluated: *Just in Time–Delivery Times*

Table 14.2 Latent variable validation simple Model B: *Just in Time–Delivery Times*

Coefficients	*Just in Time*	*Delivery Times*
R-squared (R^2)		0.289
Adjusted R^2		0.286
Composite reliability	0.858	0.840
Cronbach's alpha index (CAI)	0.770	0.718
Average variance extracted (AVE)	0.752	0.724
Full collinearity VIF	1.401	1.401
Q-Squared (Q^2)		0.291

and similar to its corresponding R^2 value, indicating that there is enough non-parametric validity.

- The two latent variables have enough internal validity, since both the composite reliability index and the CAI have values higher than 0.7 (remember that the difference in this two indices is the estimation procedure, including r excluding the sample size).
- There is enough convergent validity in the two latent variables, since AVE values are higher than 0.5.
- The two latent variables are free from internal collinearity problems since the VIF values are lower than 3.3.

Once the latent variables were tested, the model must be assessed as discussed in the methodology chapter. Ten model fit and quality indices were used for this evaluation. The results are listed below:

- Average Path Coefficient (APC) = 0.538, $P < 0.001$
- Average R-Squared (R^2) (ARS) = 0.289, $P < 0.001$
- Average Adjusted R-Squared (AARS) = 0.286, $P < 0.001$
- Average block VIF (AVIF) not available
- Average Full collinearity VIF (AFVIF) = 1.401, acceptable if ≤ 5, ideally ≤ 3.3
- Tenenhaus GoF (GoF) = 0.462, small ≥ 0.1, medium $\geq$ 0.25, large ≥ 0.36
- Simpson's Paradox Ratio (SPR) = 1.000, acceptable if ≥ 0.7, ideally = 1
- R-Squared Contribution Ratio (RSCR) = 1.000, acceptable if ≥ 0.9, ideally = 1
- Statistical Suppression Ratio (SSR) = 1.000, acceptable if ≥ 0.7
- Nonlinear Bivariate Causality Direction Ratio (NLBCDR) = 1.000, acceptable if ≥ 0.7

As can be observed, the model meets the necessary quality and fit requirements. The model has enough predictive validity, does not have collinearity problems, and the relationships are appropriately proposed in terms of sense and direction. The model can now be interpreted accordingly.

14.2.2.3 Interpretation of Simple Model B

Once the latent variables and the model were validated, the research hypothesis depicted in Fig. 12.5 can be interpreted. This interpretation is proposed below:

H_1. In the manufacturing industry, there is enough statistical evidence to claim that *Just in Time* implementation has a positive direct effect on *Delivery Times*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.538 standard deviations.

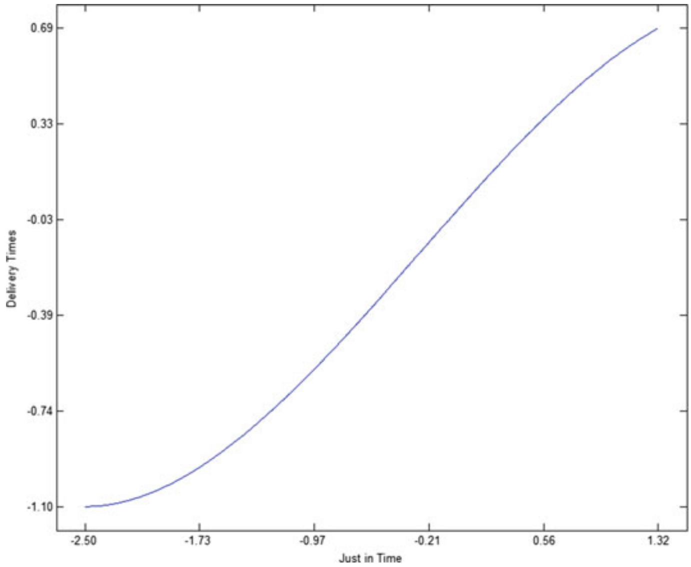

Fig. 14.6 Relationship standardized values between *Just in Time and Delivery Times*

The validated relationship implies that JIT implementation and inventory management allow companies to meet scheduled delivery times as promised, in an agile manner, and in the correct amount. Figure 14.6 illustrates the relationship between both latent variables—*Just in Time* and *Delivery Times*—once their values are standardized. The *x*-axis corresponds to the *Just in Time* philosophy, whereas the *y*-axis corresponds to *Delivery Times*.

The following interpretations for Fig. 14.6 can be discussed below:

- The relationship between the two latent variables is almost linear, thereby implying that as JIT implementation increases, *Delivery Times* improve.
- The relationship shows an S-shaped curve. Initially, the value is low; then, it increases rapidly. Finally, the relationship stabilizes once it reaches its maximum value.

14.3 Summary of Simple Relations: Manufacturing Practices–Performance (Benefits)

In this chapter, four latent variables as manufacturing practices are studied, and its impacts on eight supply chain performance benefits, represented by eight dependent latent variables. It might be a wearisome task to thoroughly discuss and depict the 32 relationships that can be proposed between the four major manufacturing

Table 14.3 Latent variable coefficients: *Manufacturing Practices*

Coefficient	*Just in Time*	*Advanced Manufacturing Technology*	*Total Quality Management*	*Maintenance*
Composite reliability	0.858	0.869	0.911	0.897
Cronbach's alpha index (CAI)	0.770	0.773	0.854	0.827
Average variance extracted (AVE)	0.752	0.688	0.774	0.745

practices and the eight supply chain performance benefits. Therefore, this subsection aims at summarizing such a large amount of information. Table 14.3 reports the latent variable coefficients estimated for the latent variables that stand for the four manufacturing practices. As for the supply chain performance variables, their validation was discussed in Chap. 11.

14.3.1 *Latent Variable Validation for* Manufacturing Practices

The first step in a model validation process involves validating the latent variables. Table 14.3 reports the coefficients estimated for the seven regional impact factors. Notice that coefficients R^2, adjusted R^2, and Q^2 are not estimated, since manufacturing practices factors are considered to be independent latent variables, and thus, cannot be explained by other latent variables.

According to the estimated coefficients, we can discuss the following validation results:

- The four latent variables have appropriate internal validity, since both the composite reliability and the CAI have values higher than 0.7.
- According to the AVE values (all higher than 0.5), all the latent variables have enough convergent validity.

The following section proposes the 32 relationships that are proposed to explore the impact of the four *Manufacturing practices* on the eight supply chain *Performance* benefits. The section is divided into four parts.

14.3.2 *Simple Hypotheses:* Manufacturing Practices–Benefits

This subsection introduces the hypotheses that directly relate each manufacturing practice with each supply chain performance benefit. Below discusses the set of theorized relationships between the four manufacturing practices considered and the eight supply chain performance benefits.

14.3.2.1 Hypotheses: *Total Quality Management–Benefits*

The theorized relationships between *Total Quality Management* implementation and supply chain performance *Benefits* in the manufacturing industry

H_1. *Total Quality Management* implementation has a positive direct impact on product *Delivery Times*.
H_2. *Total Quality Management* implementation has a positive direct impact on product *Quality*.
H_3. *Total Quality Management* implementation has a positive direct impact on production process *Flexibility*.
H_4. *Total Quality Management* implementation has a positive direct impact on after sales *Customer Service*.
H_5. *Total Quality Management* implementation has a positive direct impact on production process *Agility*.
H_6. *Total Quality Management* implementation has a positive direct impact on corporate *Financial Performance*.
H_7. *Total Quality Management* implementation has a positive direct impact on *Inventory* management performance.
H_8. *Total Quality Management* implementation has a positive direct impact on *Transportation* benefits.

14.3.2.2 Hypotheses: *Just in Time–Benefits*

The research hypotheses that associate *Just in Time* as a manufacturing practice with eight supply chain performance benefits are:

H_1. *Just in Time* implementation has a positive direct impact on product *Delivery Times*.
H_2. *Just in Time* implementation has a positive direct impact on product *Quality*.
H_3. *Just in Time* implementation has a positive direct impact on production process *Flexibility*.
H_4. *Just in Time* implementation has a positive direct impact on after sales *Customer Service*.
H_5. *Just in Time* implementation has a positive direct impact on production process *Agility*.
H_6. *Just in Time* implementation has a positive direct impact on corporate *Financial Performance*.

H_7. *Just in Time* implementation has a positive direct impact on *Inventory* management performance.
H_8. *Just in Time* implementation has a positive direct impact on *Transportation* benefits.

14.3.2.3 Hypotheses: *Maintenance–Benefits*

The following paragraphs discuss the relationships to be tested between machinery and equipment *Maintenance* programs and eight supply chain performance benefits:

H_1. *Maintenance* programs have a positive direct impact on product *Delivery Times*.
H_2. *Maintenance* programs have a positive direct impact on product *Quality*.
H_3. *Maintenance* programs have a positive direct impact on production process *Flexibility*.
H_4. *Maintenance* programs have a positive direct impact on after sales *Customer Service*.
H_5. *Maintenance* programs have a positive direct impact on production process *Agility*.
H_6. *Maintenance* programs have a positive direct impact on corporate *Financial Performance*.
H_7. *Maintenance* programs have a positive direct impact on *Inventory* management performance.
H_8. *Maintenance* programs have a positive direct impact on *Transportation* benefits.

14.3.2.4 Hypotheses: *Advanced Manufacturing Technology–Benefits*

Installed machinery and equipment have a certain impact on supply chain performance. Machines that work properly always guarantee appropriate material flows. Therefore, this section discusses the theorized relationships to be tested between *Advanced Manufacturing Systems* (AMT) and supply chain performance.

H_1. *Advanced Manufacturing Technology* implemented in production processes has a positive direct impact on product *Delivery Times*.
H_2. *Advanced Manufacturing Technology* implemented in production processes has a positive direct impact on product *Quality*.
H_3. *Advanced Manufacturing Technology* implemented in production processes has a positive direct impact on production process *Flexibility*.
H_4. *Advanced Manufacturing Technology* implemented in production processes has a positive direct impact on after sales *Customer Service*.
H_5. *Advanced Manufacturing Technology* implemented in production processes has a positive direct impact on production process *Agility*.

H_6. *Advanced Manufacturing Technology* implemented in production processes has a positive direct impact on corporate *Financial Performance*.
H_7. *Advanced Manufacturing Technology* implemented in production processes has a positive direct impact on *Inventory* management performance.
H_8. *Advanced Manufacturing Technology* implemented in production processes has a positive direct impact on *Transportation* benefits.

This book explores manufacturing practices through four latent variables. Two of these factors were validated in previous models; however, Table 14.3 summarizes the validation results of the four latent variables to provide necessary background for our following discussion. Note that the table reports only three coefficients: composite reliability, Cronbach's alpha, and AVE. According to the estimated coefficients, we can discuss the following validation results:

- The four latent variables have appropriate internal validity, since both the composite reliability and the CAI have values higher than 0.7.
- According to the AVE values (all higher than 0.5), all the latent variables have enough convergent validity.

14.3.3 *Latent Variable Validation Process:* Supply Chain Performance (Benefits)

The eight latent variables that correspond to the eight supply chain performance benefits were tested and successfully validated in Chap. 11. Therefore, the following section can successfully proceed to the analysis of the 32 relationships discussed above. For further information on the performance variables, please consult Table 11.3 in Chap. 11.

14.3.4 *Hypotheses Validation:* Manufacturing Practices–Benefits

Table 14.4 summarizes the results of the analysis performed on the 32 hypotheses. Each hypothesis or relationship includes a β value, a P value, and an R^2 value. The β coefficient is a measure of dependency, whereas P is an indicator of statistical significance. Relationships that are statistically significant have a p value lower than 0.05. Finally, R^2 is a measure of explained variance associated with the dependent latent variables. As the table reports, dependent latent variables are listed in the first column, whereas independent latent variables (i.e., manufacturing practices) are found in the first row.

Table 14.4 Hypotheses validation: *Manufacturing Practices–Benefits*

To	From			
	Total Quality Management	*Advanced Manufacturing Technology*	*Maintenance*	*Just in Time*
Delivery Times	$\beta = 0.490$ ($P < 0.001$) $R^2 = 0.240$	$\beta = 0.504$ ($P < 0.001$) $R^2 = 0.254$	$\beta = 0.465$ ($P < 0.001$) $R^2 = 0.216$	$\beta = 0.538$ ($P < 0.001$) $R^2 = 0.289$
Quality	$\beta = 0.411$ ($P < 0.001$) $R^2 = 0.169$	$\beta = 0.410$ ($P < 0.001$) $R^2 = 0.168$	$\beta = 0.369$ ($P = 0.006$) $R^2 = 0.136$	$\beta = 0.366$ ($P < 0.001$) $R^2 = 0.134$
Flexibility	$\beta = 0.518$ ($P < 0.001$) $R^2 = 0.269$	$\beta = 0.596$ ($P < 0.001$) $R^2 = 0.359$	$\beta = 0.566$ ($P = 00.01$) $R^2 = 0.321$	$\beta = 0.570$ ($P < 0.001$) $R^2 = 0.325$
Customer Service	$\beta = 0.397$ ($P < 0.001$) $R^2 = 0.158$	$\beta = 0.441$ ($P < 0.001$) $R^2 = 0.195$	$\beta = 0.418$ ($P = 0.016$) $R^2 = 0.175$	$\beta = 0.43$ ($P < 0.001$) $R^2 = 0.185$
Agility	$\beta = 0.469$ ($P < 0.001$) $R^2 = 0.220$	$\beta = 0.541$ ($P < 0.001$) $R^2 = 0.293$	$\beta = 0.465$ ($P < 0.001$) $R^2 = 0.217$	$\beta = 0.439$ ($P < 0.001$) $R^2 = 0.220$
Financial Performance	$\beta = 0.363$ ($P < 0.001$) $R^2 = 0.132$	$\beta = 0.346$ ($P < 0.001$) $R^2 = 0.119$	$\beta = 0.344$ ($P < 0.001$) $R^2 = 0.118$	$\beta = 0.360$ ($P < 0.001$) $R^2 = 0.130$
Inventory	$\beta = 0.384$ ($P < 0.001$) $R^2 = 0.148$	$\beta = 0.444$ ($P < 0.001$) $R^2 = 0.198$	$\beta = 0.371$ ($P = 007$) $R^2 = 0.137$	$\beta = 0.483$ ($P < 0.001$) $R^2 = 0.233$
Transportation	$\beta = 0.421$ ($P < 0.001$) $R^2 = 0.177$	$\beta = 0.434$ ($P < 0.001$) $R^2 = 0.188$	$\beta = 0.404$ ($P < 0.001$) $R^2 = 0.164$	$\beta = 0.427$ ($P < 0.001$) $R^2 = 0.182$

14.3.5 Conclusions for Simple Hypotheses: Manufacturing Practices–Benefits

14.3.5.1 Simple Hypotheses: *Total Quality Management–Benefits*

This section interprets the results found in the previous table with respect to the significance of the hypotheses and the value of the effect:

H_1. There is enough statistical evidence to claim that *Total Quality Management* implementation has a positive direct impact on product *Delivery Times*. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.490 standard deviations. Moreover, *Total Quality Management* explains 24% of the variability of *Delivery Times*.
H_2. There is enough statistical evidence to claim that *Total Quality Management* implementation has a positive direct impact on product *Quality*. When the first latent variable increases by one standard deviation, the second latent variable

increases by 0.411 standard deviations. Moreover, *Total Quality Management* explains 16.9% of the variability of *Quality*.

H_3. There is enough statistical evidence to claim that *Total Quality Management* implementation has a positive direct impact on production *Flexibility*. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.518 standard deviations. Moreover, *Total Quality Management* explains 26.9% of the variability of *Flexibility*.

H_4. There is enough statistical evidence to claim that *Total Quality Management* implementation has a positive direct impact on after sales *Customer Service*. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.397 standard deviations. Moreover, *Total Quality Management* explains 15.8% of the variability of *Customer Service*.

H_5. There is enough statistical evidence to claim that *Total Quality Management* implementation has a positive direct impact on production process *Agility*. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.469 standard deviations. Moreover, *Total Quality Management* explains 22% of the variability of *Agility*.

H_6. There is enough statistical evidence to claim that *Total Quality Management* implementation has a positive direct impact on corporate *Financial Performance*. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.363 standard deviations. Moreover, *Total Quality Management* explains 13.2% of the variability of *Financial Performance*.

H_7. There is enough statistical evidence to claim that *Total Quality Management* implementation has a positive direct impact on *Inventory* management performance. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.384 standard deviations. Moreover, *Total Quality Management* explains 14.8% of the variability of *Inventory*.

H_8. There is enough statistical evidence to claim that *Total Quality Management* implementation has a positive direct impact on *Transportation* benefits. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.421 standard deviations. Moreover, *Total Quality Management* explains 17.7% of the variability of *Transportation*.

The two highest β values reported in Table 14.5 stand for the two most important benefits of TQM implementation. First, the relationship between *TQM* and *Flexibility* implies that companies cannot be flexible if they do not rely on effective quality management programs and systems. Second, the relationship between *TQM* and *Delivery Times* demonstrates that those companies that guarantee *Quality* in production processes successfully meet scheduled *Delivery Times*. However, the lowest β value highlights the weakest impact of *TQM* on supply chain performance, namely on *Financial Performance.* The value of this relationship suggests that companies truly wish to be flexible and meet *Delivery Times*, whereas their *Financial Performance* is a secondary attribute.

Table 14.5 Latent variable validation complex Model C: *Manufacturing Practices*

Coefficient	*Just in Time*	*Advanced Manufacturing Technology*	*Total Quality Management*	*Maintenance*
R-squared (R^2)	0.461		0.397	0.473
Adjusted R^2	0.454		0.394	0.468
Composite reliability	0.858	0.869	0.911	0.897
Cronbach's alpha index (CAI)	0.670	0.773	0.854	0.827
Average variance extracted (AVE)	0.752	0.688	0.774	0.745
Full collinearity VIF	1.797	2.038	2.073	1.891
Q-squared (Q^2)	0.464		0.396	0.474

14.3.5.2 Simple Hypotheses: *Just in Time–Benefits*

In this subsection is interpreted the results found in Table 14.5 with respect to the relationships between *Just in Time* as a manufacturing practice and supply chain performance:

H_1. There is enough statistical evidence to claim that *Just in Time* implementation has a positive direct impact on product *Delivery Times*. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.538 standard deviations. Moreover, *Just in Time* explains 28.9% of the variability of *Delivery Times*.

H_2. There is enough statistical evidence to claim that *Just in Time* implementation has a positive direct impact on product *Quality*. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.366 standard deviations. Moreover, *Just in Time* explains 13.4% of the variability of *Quality*.

H_3. There is enough statistical evidence to claim that *Just in Time* implementation has a positive direct impact on production process *Flexibility*. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.570 standard deviations. Moreover, *Just in Time* explains 32.5% of the variability of *Flexibility*.

H_4. There is enough statistical evidence to claim that *Just in Time* implementation has a positive direct impact on after sales *Customer Service*. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.430 standard deviations. Moreover, *Just in Time* explains 18.5% of the variability of *Customer Service*.

H_5. There is enough statistical evidence to claim that *Just in Time* implementation has a positive direct impact on production process *Agility*. When the first latent variable increases by one standard deviation, the second latent variable increases by

0.439 standard deviations. Moreover, *Just in Time* explains 22% of the variability of *Agility*.

H_6. There is enough statistical evidence to claim that *Just in Time* implementation has a positive direct impact on corporate *Financial Performance*. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.360 standard deviations. Moreover, *Just in Time* explains 13% of the variability of *Financial Performance*.

H_7. There is enough statistical evidence to claim that *Just in Time* implementation has a positive direct impact on *Inventory* management performance. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.483 standard deviations. Moreover, *Just in Time* explains 23.3% of the variability of *Inventory*.

H_8. There is enough statistical evidence to claim that *Just in Time* implementation has a positive direct impact on *Transportation* benefits. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.427 standard deviations. Moreover, *Just in Time* explains 18.2% of the variability of *Transportation*.

According to Table 14.5, the major benefit of the four manufacturing practices is *Flexibility*. As regards JIT implementation, its impact on flexible production processes ($\beta = 0.570$) demonstrates that the JIT philosophy provides a vast array of problem-solving and customer satisfaction methods that can be implemented in the production process. Likewise, the results indicate that JIT also plays a key role in *Delivery Times*, thereby allowing companies to guarantee on-time deliveries to their customers.

As for its weakest impact, JIT implementation can be discussed with respect to *Financial Performance*. Such results suggest that JIT is not the first priority in companies or it is a consequence of preceding performance *Benefits*. In other words, it is possible that manager's chiefly focus on gaining *Flexibility* and *Agility* and meeting promised *Delivery Times*, whereas corporate *Financial Performance* is a result of the success of these aspects. In this sense, it is important to mention that *Flexibility, Agility*, and *Delivery Times* are aspects that customers can easily see and thus value more. Consequently, they are prioritized among companies and supply chain systems.

14.3.5.3 Simple Hypotheses: *Maintenance–Benefits*

This subsection interprets the results found in Table 14.4 with respect to the relationships between *Maintenance* programs and supply chain performance benefits.

H_1. There is enough statistical evidence to claim that *Maintenance* programs have a positive direct impact on product *Delivery Times*. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.465

standard deviations. Moreover, *Maintenance* explains 21.6% of the variability of *Delivery Times*.

H_2. There is enough statistical evidence to claim that *Maintenance* programs have a positive direct impact on product *Quality*. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.369 standard deviations. Moreover, *Maintenance* explains 13.6% of the variability of *Quality*.

H_3. There is enough statistical evidence to claim that *Maintenance* programs have a positive direct impact on production process *Flexibility*. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.566 standard deviations. Moreover, *Maintenance* explains 32.1% of the variability of *Flexibility*.

H_4. There is enough statistical evidence to claim that *Maintenance* programs have a positive direct impact on after sales *Customer Service*. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.418 standard deviations. Moreover, *Maintenance* explains 17.5% of the variability of *Customer Service*.

H_5. There is enough statistical evidence to claim that *Maintenance* programs have a positive direct impact on production process *Agility*. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.465 standard deviations. Moreover, *Maintenance* explains 21.7% of the variability of *Agility*.

H_6. There is enough statistical evidence to claim that *Maintenance* programs have a positive direct impact on corporate *Financial Performance*. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.344 standard deviations. Moreover, *Maintenance* explains 11.8% of the variability of *Financial Performance*.

H_7. There is enough statistical evidence to claim that *Maintenance* programs have a positive direct impact on *Inventory* management performance. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.375 standard deviations. Moreover, *Maintenance* explains 13.7% of the variability of *Inventory*.

H_8. There is enough statistical evidence to claim that *Maintenance* programs have a positive direct impact on *Transportation* benefits. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.404 standard deviations. Moreover, *Maintenance* explains 16.4% of the variability of *Transportation*.

According to the results summarized in Table 14.5, the most important benefit of implementing *Maintenance* programs is *Flexibility,* as in the two previous sections. Such results highlight the importance of flexible businesses in such a globalized and customer-focused world, where batch sizes become smaller and more varied. One can only imagine the consequences of machine failures and undesired stoppages within the production process: they compromise *Flexibility*, and consequently *Delivery Times*, at the same time that they increase undesired *Inventory* levels.

Two other most noteworthy benefits of *Maintenance* programs are *Delivery Times* and *Agility*. In other words, *Maintenance* programs can be associated with customer satisfaction. On the other hand, surprisingly, *Financial Performance* is the least important outcome of *Maintenance* practices, since this relationship shows the lowest β value. Such results might imply that the top priority for managers is customer satisfaction, rather than profits, since *Financial Performance* is thought as a consequence of product acceptation.

14.3.5.4 Simple Hypotheses: *Advanced Manufacturing Technology–Benefits*

This section proposes the simple hypotheses that relate Advanced Manufacturing Technology to each one of the supply chain performance benefits.

H_1. There is enough statistical evidence to claim that *Advanced Manufacturing Technology* has a positive direct impact on product *Delivery Times.* When the first latent variable increases by one standard deviation, the second latent variable increases by 0.504 standard deviations. Moreover, *Advanced Manufacturing Technology* explains 25.4% of the variability of *Delivery Times*.

H_2. There is enough statistical evidence to claim that *Advanced Manufacturing Technology* has a positive direct impact on product *Quality.* When the first latent variable increases by one standard deviation, the second latent variable increases by 0.410 standard deviations. Moreover, *Advanced Manufacturing Technology* explains 16.8% of the variability of *Quality*.

H_3. There is enough statistical evidence to claim that *Advanced Manufacturing Technology* has a positive direct impact on *Flexibility.* When the first latent variable increases by one standard deviation, the second latent variable increases by 0.596 standard deviations. Moreover, *Advanced Manufacturing Technology* explains 35.9% of the variability of *Flexibility*.

H_4. There is enough statistical evidence to claim that *Advanced Manufacturing Technology* has a positive direct impact on after sales *Customer Service.* When the first latent variable increases by one standard deviation, the second latent variable increases by 0.441 standard deviations. Moreover, *Advanced Manufacturing Technology* explains 19.5% of the variability of *Customer Service*.

H_5. There is enough statistical evidence to claim that *Advanced Manufacturing Technology* has a positive direct impact on *Agility.* When the first latent variable increases by one standard deviation, the second latent variable increases by 0.541 standard deviations. Moreover, *Advanced Manufacturing Technology* explains 29.3% of the variability of *Agility*.

H_6. There is enough statistical evidence to claim that *Advanced Manufacturing Technology* has a positive direct impact on corporate *Financial Performance*. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.346 standard deviations. Moreover, *Advanced Manufacturing Technology* explains 11.9% of the variability of *Financial Performance*.
H_7. There is enough statistical evidence to claim that *Advanced Manufacturing Technology* has a positive direct impact on *Inventory* management performance. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.444 standard deviations. Moreover, *Advanced Manufacturing Technology* explains 25.4% of the variability of *Inventory*.
H_8. There is enough statistical evidence to claim that *Advanced Manufacturing Technology* has a positive direct impact on *Transportation* benefits. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.434 standard deviations. Moreover, *Advanced Manufacturing Technology* explains 18.8% of the variability of *Transportation*.

As previously mentioned, the major benefit of manufacturing practices is production *Flexibility* ($\beta = 0.596$). Such results imply that AMT implemented in the production process has positive effects on the multiple alternatives that manufacturers adopt to deliver their products on time while simultaneously solving production problems that might arise. The statistical results for the relationship between *AMT* and *Flexibility* are consistent with the fact that highly AMT can be reprogrammed according to the technical specifications of products. Moreover, companies with effective and efficient AMT have shorter setup times thanks to the implementation of practices such as SMED and maintenance programs.

The second most important benefit of AMT is *Agility* ($\beta = 0.541$), thereby implying that *AMT* systems allow manufacturing companies to meet customer needs in an agile manner. Conversely, the lowest impact of AMT is perceived on *Financial Performance*. This phenomenon is consistent across the four manufacturing practices and reflects a prioritization trend: manufacturing companies focus on *Flexibility* and *Agility* since they view *Financial Performance* as the consequence. In conclusion, dynamic production systems that rapidly meet customer needs guarantee customer satisfaction and thus increase profits.

14.4 Complex Models: Relationships Among Manufacturing Practices

This section explores how *Manufacturing Practices* are interrelated to comprise the importance in supply chain performance. Two complex models are presented, Model C and Model D.

14.4.1 Complex Model C: Manufacturing Practices

The model assumes that companies employ production machinery and tools that can be little modified or adjusted. Therefore, *Manufacturing Advanced Technology* is considered to be the independent latent variable, since it is the basis for product *Quality* planning, feasible *Maintenance* programs, and JIT deliveries. Consequently, it is assumed that *Just in Time* is the dependent latent variable. As a result, it is located in the bottom-right corner of the figure. In summary, the model assumption is that *JIT* deliveries depend on installed technology capacity, quality management, and *Maintenance* programs. The complex model developed in this section comprises the following latent variables:

- *Total Quality Management* (3 observed variables)
- *Just in Time* (2 observed variables)
- *Maintenance* (3 observed variables)
- *Advanced Manufacturing Technology* (3 observed variables)

For further information regarding the observed variables comprised in the latent variables, please consult the methodology chapter and the survey sample in the appendix section.

14.4.1.1 Hypotheses Formulation: Complex Model C

The model associates four latent variables and 11 observed variables. The goal is to determine the impact of *Advanced Manufacturing Technology* on *Just in Time* deliveries, where aspects such as quality management and machinery *Maintenance* are taken into account. Figure 14.7 depicts the model with six research hypotheses

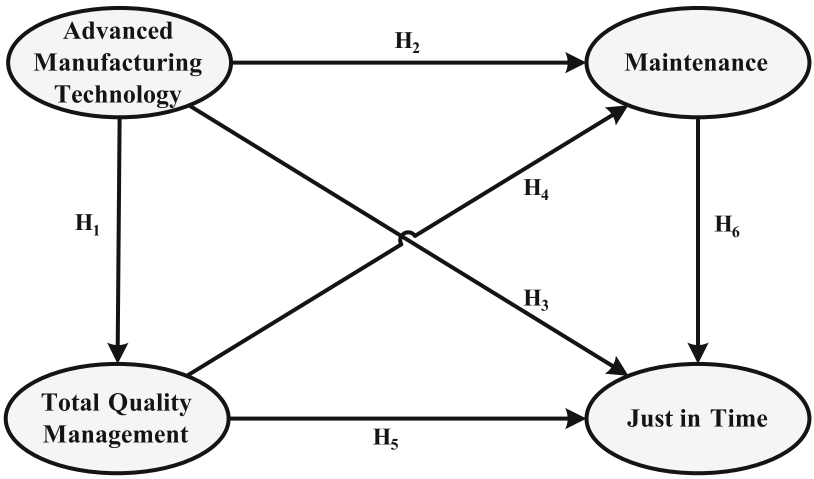

Fig. 14.7 Complex Model C proposed: *Manufacturing Practices*

to be tested in order to validate the interrelationships among *Manufacturing Practices*.

Total Quality Management is easier if it is implemented along with *Advanced Manufacturing Technology.* AMT systems are more precise and easy to calibrate; moreover, they provide a pleasant man–machine interaction and thus improve decision making (Goyal and Grover 2012). AMT can be employed not only in the production process, but also at earlier stages, including raw material supply and distribution. In other words, AMT must be implemented from the moment the product is designed to the moment the final product is delivered to customers (Singhry et al. 2016). From this perspective, AMT systems increase production agility and speed, two top customer priorities (Singh and Singh 2012).

Another important aspect of AMT is their reliability. Reliable operations minimize costs, especially in terms of audits, and thus reduce waste. In turn these benefits reflect on the *Quality* of the final product (Singh and Singh 2012). In a study conducted by Bolatan et al. (2016) in companies located in Turkey, the authors concluded that *AMT* provided both *Total Quality Management* benefits and reached desired quality levels. To support such claims in the Mexican manufacturing industry, the first research hypothesis of complex Model C can read as follows:

H_1. *Advanced Manufacturing Systems* have a positive direct effect on *Total Quality Management*.

Even though *AMT* is more sophisticated than regular manufacturing technology, their *Maintenance* is much easier. *AMT* systems include sensors to determine the state of the system components, thereby preventing machines to be insufficiently or incorrectly calibrated (Oliveira et al. 2016). *AMT* systems facilitate decision making with regards system and machinery *Maintenance*, as they provide a detailed record of the time when each system component is used. This allows companies to properly schedule planned stoppages. Additionally, *ATM* allows companies to perform remote *Maintenance* and technological support without the physical intervention of experts and technicians. Remote *Maintenance* involves a set of technology and software tools that live on a company's servers (Mourtzis et al. 2017). There is evidence of the impact of *AMT* on corporate benefits when it is implemented along with lean manufacturing tools (Arslankaya and Atay 2015). In other words, *AMT* has an impact on technical performance aspects. In this sense, the second research hypothesis can be proposed as follows:

H_2. *Advanced Manufacturing Technology* has a positive direct effect on *Maintenance* programs implemented for production machinery and tools.

The *Total Quality Management* approach relies on multiple techniques and tools, not only on paper-based plans and programs; it implies actions. One of the most useful TQM techniques is *Maintenance*, which focuses on providing the necessary support to production machinery and tools in order to ensure their optimal conditions (Kiran 2017a). Miscalibrated machines fail to do their job appropriately, which implies that companies are unable to meet technical product specifications. Consequently, products are reprocessed at the same time waste increases (Gouiaa-Mtibaa et al. 2018). Similarly, *Maintenance* programs are lean manufacturing tools that support *Quality*. They guarantee on-time deliveries—an aspect that is highly valued by customers—and are a source of motivation. In this sense, planned stoppages and changeovers prevent operators from feeling disappointed when production goals are not met (Sadikoglu and Zehir 2010). Following this discussion, it is possible to propose the third research hypothesis of Model C as follows:

H_3. *Total Quality Management* implementation has a positive direct impact on *Maintenance* programs implemented for production machinery and tools.

ATM plays an important role in JIT deliveries (Alcaraz et al. 2016; Aravindan and Punniyamoorthy 2002). Moreover, it facilitates an easy organizational restructuration when companies had to undergo modifications (Choe 2004). Likewise, *AMT* is more reliable and agile and contribute to quality improvements. In this sense, the JIT philosophy can be easily implemented in highly technological production systems (Nath and Sarkar 2017). Companies with obsolete technology can compromise both their flexibility and their product delivery performance, since their production machinery and equipment can be hardly repaired (Bai and Sarkis 2017).

In a research work that reports important *AMT* benefits, authors García Alcaraz et al. (2012) place *JIT* at the top of the list. Similarly, it is argued that early market penetration and on-time deliveries are *AMT* benefits that companies must not take for granted (Percival and Cozzarin 2010). However, other researchers argue that perhaps the major drawback of *AMT* is the high costs incurred in their *Maintenance*. In spite of that *AMT* are also more environmentally friendly than traditional manufacturing technology (Bai and Sarkis 2017). To explore the relationship between *AMT* and *JIT* in the Mexican manufacturing industry, the fourth research hypothesis can be proposed below:

H_4. *Advanced Manufacturing Technology* has a positive direct effect on *Just in Time* systems.

To some authors, *TQM* is viewed as a set of tools, rather than an isolated process. In their work, Suwandej (2015) listed a series of factors influencing *TQM* and found *JIT* as one of the most important. Likewise, Kiran (2017b) analyzed the evolution of the approach and managed to define quality as a process through which manufacturers deliver products to customers on time, in the right amount, and by meeting the required technical specifications. That said, on-time deliveries are only guaranteed with *JIT* implementation. From a similar perspective, Friedli et al. (2010) explored *TQM* and *JIT* and found a strong relationship between them. The authors claim that many programs supporting *JIT* also facilitate TQM. For instance, the goal of preventive *Maintenance* programs is to provide attention to equipment and facilities to ensure their proper functionality and to reduce the rate of deterioration. In turn, these conditions ensure a continuous production flow that does not compromises *Delivery Times.* As Singh et al. (2013) argue, TQM has an impact on production flow and thus on process flexibility. Therefore, to explore the relationship between *TQM* and *JIT* in the manufacturing industry, the fifth research hypothesis can read as follows:

H_5. *Total Quality Management* has a positive direct effect on *Just in Time* implementation.

Maintenance plans must be part of a consolidated quality program that is concerned with the company's ability to comply with customer requirements in terms of technical specifications and delivery times (McCarthy and Rich 2015). Furthermore, quality programs must be continuously reviewed to determine and measure their success and make modifications accordingly. Some machines that are unique in the production process are invaluable assets to companies. Consequently, any failure, underperformance, or undesired stoppage from them disrupts all the company operations (Singh et al. 2013), thereby delaying deliveries and affecting *JIT* compliance. This situation is reportedly common in the mining industry (Chlebus et al. 2015).

Companies that do not prioritize *Maintenance* tasks and or do not merge them with other manufacturing tools might have to deal with a significant number of customer complaints. In fact, Rodrigues and Hatakeyama (2006) consider that poor or little *Maintenance* planning is a major cause of failure in total preventive maintenance (TPM) programs. Meanwhile, Mwanza and Mbohwa (2015) claim that little planning makes quality management more challenging, and consequently, compromises JIT deliveries. In this sense, the last research hypothesis of Model C can be proposed below:

H_6. The implementation of *Maintenance* programs has a positive direct effect on *Just in Time* deliveries.

14.4.1.2 Latent Variable Validation Process of Complex Model C

The previous sections proposed a series of relationships that could be depicted with simple models. These simple relationships associate every manufacturing practice with the eight supply chain performance benefits. The model presented in this section is more complex in the sense that it integrates more latent variables and thus proposes multiple research hypotheses. Table 14.5 summarizes the results of the validation tests performed on the four latent variables. The interpretations of such results will not be further discussed, since they have already been addressed in earlier sections.

14.4.1.3 Results of Complex Model C: *Manufacturing Practices*

Figure 14.8 depicts Model C after being run to test the feasibility of the relationships. As in previous models, each hypothesized relationship includes a β value, a p value, and an R^2 value. The β coefficient is a measure of dependency, whereas the P value indicates statistical significance. Relationships that are statistically significant have a P value lower than 0.05. Finally, R^2 is a measure of explained variance that is associated with dependent latent variables.

14.4.1.4 Efficiency indices in complex Model C: *Manufacturing Practices*

Ten model fit and quality indices were estimated to test the feasibility of the model. For further information on these indices, consult the methodology chapter.

- Average Path Coefficient (APC) = 0.364, $P < 0.001$
- Average R-Squared (ARS) = 0.444, $P < 0.001$
- Average Adjusted R-Squared (AARS) = 0.439, $P < 0.001$
- Average block VIF (AVIF) = 1.756, acceptable if ≤ 5, ideally ≤ 3.3
- Average Full collinearity VIF (AFVIF) = 1.950, acceptable if ≤ 5, ideally ≤ 3.3
- Tenenhaus GoF (GoF) = 0.573, small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36
- Simpson's Paradox Ratio (SPR) = 1.000, acceptable if ≥ 0.7, ideally = 1

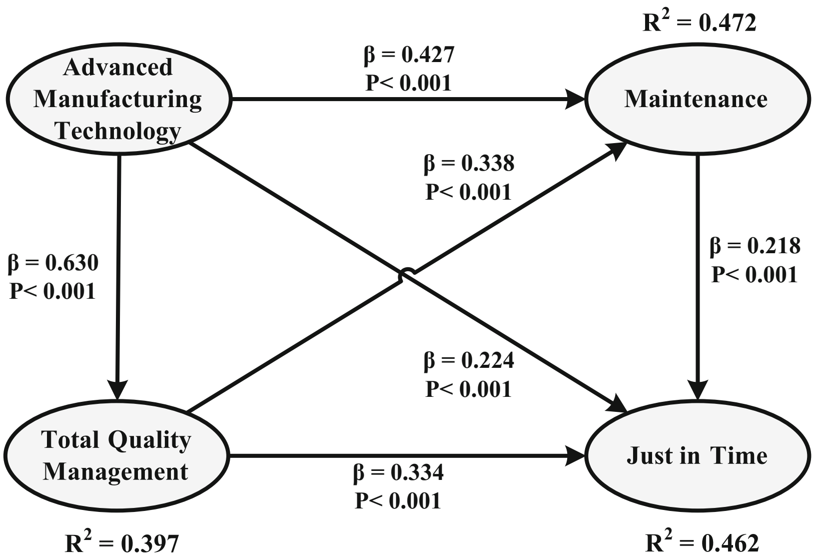

Fig. 14.8 Complex Model C evaluated: *Manufacturing Practices*

- R-Squared Contribution Ratio (RSCR) = 1.000, acceptable if ≥ 0.9, ideally = 1
- Statistical Suppression Ratio (SSR) = 1.000, acceptable if ≥ 0.7
- Nonlinear Bivariate Causality Direction Ratio (NLBCDR) = 1.000, acceptable if ≥ 0.7
- According to these results, we can conclude that the model has enough predictive validity, since the R^2 and adjusted R^2 values are higher than 0.02, and their corresponding *P* values are lower than 0.05. Likewise, AVIF and AFVIF values confirm that the model is free from collinearity problems, whereas the Tenenhaus GoF indicates a good model fit. Finally, according to the remaining indices, the research hypotheses do not have directionality problems. The model can now be interpreted accordingly.

14.4.1.5 Direct Effects

The direct effects are used to validate the research hypotheses proposed in Fig. 14.7. According to the test results depicted in Fig. 14.8 (see *P* values and β values), it is possible to propose the following conclusions:

H_1. There is enough statistical evidence to state that *Advanced Manufacturing Technology* has a positive direct effect on *Total Quality Management*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.630 standard deviations.
H_2. There is enough statistical evidence to state that *Advanced Manufacturing Technology* has a positive direct effect on *Maintenance* programs, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.427 standard deviations.
H_3. There is enough statistical evidence to state that *Total Quality Management* has a positive direct effect on *Maintenance* programs, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.338 standard deviations.
H_4. There is enough statistical evidence to state that *Advanced Manufacturing Technology* has a positive direct effect on *Just in Time* implementation, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.224 standard deviations.
H_5. There is enough statistical evidence to state that *Total Quality Management* has a positive direct effect on *Just in Time* implementation, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.344 standard deviations.
H_6. There is enough statistical evidence to state that *Total Quality Management* has a positive direct effect on *Maintenance* programs, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.218 standard deviations.

14.4.1.6 Effect Sizes

As depicted in Fig. 14.8, latent variables *Maintenance* and *Just in Time* can be explained by more than two independent latent variables. Consequently, their corresponding R^2 values must be decomposed to determine the size of the effect from each independent latent variable. Table 14.6 summarizes the R^2 decomposition results.

Based on both Fig. 14.8 and Table 14.6, it is possible to propose the following conclusions:

- Three independent latent variables explain 46.2% of the variability of *Just in Time*. Namely, *Advanced Manufacturing Technology* explains 12.8%, *Total Quality Management* explains 12.8%, and *Maintenance* is responsible for 12.3%. Such results indicate that successful *JIT* implementation mostly depends on successful *TQM*, since this latent variable shows the largest explanatory power.
- Together, two latent variables explain 47.2% of the variability of *Maintenance*. *Advanced Manufacturing Technology* explains 27%, whereas *Total Quality Management* explains 20.2%. In other words, effective *Maintenance* programs chiefly depend on machines and equipment that operate in optimal conditions. Nevertheless, *TQM* also plays an important role.

14.4.1.7 Sum of Indirect Effects

In indirect relationships, independent latent variables have indirect effects on dependent latent variables through mediator variables. Table 14.7 summarizes the results of the indirect effects found for Model C.

According to the results summarized in Table 14.7 and Fig. 14.8, the direct relationship between *Advanced Manufacturing Technology* and *Just in Time* is only 0.224 standard deviations, yet the indirect effect is much higher, since $\beta = 0.356$. In other words, machinery *Maintenance* and *TQM* implementation play a crucial role in *JIT* implementation supported by *AMT* systems. Moreover, in this indirect relationship *AMT* explains 20.3% of the variability of *JIT*, since $R^2 = 0.203$. From a

Table 14.6 Effect sizes in complex Model C

To	From			R^2
	Advanced Manufacturing Technology	*Total Quality Management*	*Maintenance*	
Just in Time	0.128	0.211	0.123	0.462
Total Quality Management	0.397			0.397
Maintenance	0.27	0.202		0.472

Table 14.7 Sum of indirect effects in complex Model C

To	From	
	Advanced Manufacturing Technology	*Total Quality Management*
Just in Time	0.356 ($P < 0.001$) ES = 0.203	0.074 ($P = 0.047$) ES = 0.045
Maintenance	0.213 ($P < 0.001$) ES = 0.135	

different perspective, we found that the indirect relationship between *Advanced Manufacturing Technology* and *Maintenance* has a lower value than the direct relationship, yet the explanatory power is significant. In other words, when *Total Quality Management* is present, *AMT* can explain 13.5% of the variability of *Maintenance* programs, since $R^2 = 0.135$.

14.4.1.8 Total Effects

Table 14.8 reports the total effects estimated for Model C. According to such results, it is possible to provide the following interpretations:

- The largest total effects occur in the relationship between latent variables *Advanced Manufacturing Technology* and *Maintenance*, where the former explains 40.5% of the variability of the latter. These total effects include the indirect effects given through *Total Quality Management* and indicate the more technologically sophisticated *AMT* is, the easier it is to maintain them through an effective *TQM* approach.
- Other important effects occur in the relationship between *AMT* and *TQM*, where $\beta = 0.630$. These effects stand for the direct relationship between the two latent variables and demonstrate that highly qualified manufacturing machinery can guarantee quality in production processes and thus in final products.

Table 14.8 Total effects in complex Model C

To	From		
	Advanced Manufacturing Technology	*Total Quality Management*	*Maintenance*
Just in Time	0.581 ($P < 0.001$) ES = 0.331	0.418 ($P < 0.001$) ES = 0.256	0.218 ($P < 0.001$) ES = 0.123
Total Quality Management	0.630 ($P < 0.001$) ES = 0.397		
Maintenance	0.640 ($P < 0.001$) ES = 0.405	0.338 ($P < 0.001$) ES = 0.202	

- Finally, notice that the relationship between *AMT* and *JIT* implementation is prominent. The total effect is equal to 0.581 standard deviations and thus demonstrates that the level of technical sophistication of *AMT* reduces levels of inventory and improves product delivery performance.

14.4.2 *Conclusions and Industrial Implications of Complex Models:* Relationships Among Manufacturing Practices

This chapter explores the relationships between four major manufacturing practices and eight supply chain performance benefits. Then, we study how such manufacturing practices are interrelated and the effects they have among them. With respect to the research hypotheses tested and the models provided, it is possible to establish the following concluding remarks:

- The strongest direct and simple relationship between manufacturing practices and supply chain benefits involves latent variables *Advanced Manufacturing Technology* and supply chain *Flexibility*. However, the relationship between *Just in Time* and *Flexibility* is strong. Such results demonstrate that, according to data gathered in the Mexican manufacturing industry in Ciudad Juárez, having advanced manufacturing machinery and equipment improves production processes and improves machine performance and capacity utilization. Likewise, *AMT* allows production systems to become more flexible toward customer demands, which often change unpredictably. Such results also imply that Mexican manufacturing companies in Ciudad Juárez make good use of *AMT*.
- The weakest simple direct relationship involves latent variables *Maintenance* and *Financial Performance*, which indicates that *Maintenance* programs have primary purposes other than increasing profits. Some of these purposes include reducing machine stoppages and dead times. In other words, good maintenance, either predictive or preventive, prevents production disruptions and thus economic losses.
- In general, manufacturing practices chiefly impact supply chain *Flexibility*, which demonstrates that products can be successfully delivered to customers through production processes that are easily adaptable to sudden changes. Similarly, there is a strong relationship between manufacturing practices and supply chain *Agility*. In this sense, it is important that companies focus on delivering products not only with the right technical specifications, but also on time.

As regards the interrelationships among manufacturing practices, the last model (Model C) indicates that the level of technological sophistication of *AMT* systems is essential for production and product quality. Moreover, AMT systems are easy to maintain, contribute to product delivery performance, and improve overall supply chain performance.

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Chapter 15
Models of Manufacturing Practices and Integrative Model

15.1 Model A: Manufacturing Practices–Benefits

This model explores the relationships between two major manufacturing practices and two supply chain performance benefits. Namely, the model studies how *Advanced Manufacturing Technology* (*AMT*) and *Maintenance* programs impact both supply chain *Agility* and *Financial Performance*. Strong valid relationships are expected. In this case, it would be assumed that *AMT* is an independent latent variable that has an impact on all the remaining variables. On the other hand, *Financial Performance* would be considered as the dependent variable, since it would be the consequence of the remaining variables. The latent variables to be explored in this first model are the following:

Manufacturing practices:

- *Advanced Manufacturing Technology* (*AMT*) (3 items or observed variables)
  Maintenance (3 items or observed variables)

Supply chain performance benefits:

- *Agility* (5 items or observed variables)
- *Financial Performance* (3 items or observed variables)

15.1.1 Hypotheses Formulation: Model A

This model integrates four latent variables and 14 observed variables or items. Figure 15.1 depicts the six research hypotheses proposed to relate the latent variables.

L. Avelar-Sosa et al., *Evaluation of Supply Chain Performance*,
Management and Industrial Engineering,
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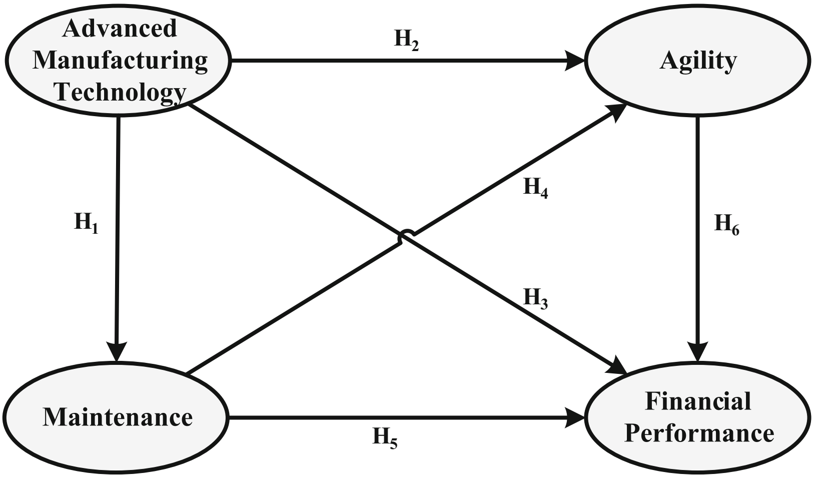

Fig. 15.1 Model A proposed: *Manufacturing Practices–Benefits*

The first research hypothesis proposes a relationship between *Advanced Manufacturing Technology* and *Maintenance* programs. This relationship was initially proposed, and also tested, in the previous chapter; therefore, it is not thoroughly discussed in this section. That said, the hypothesis can read as follows:

H_1. *Advanced Manufacturing Technology* has a positive direct effect on *Maintenance* programs implemented for manufacturing machinery and equipment.

Perhaps the major advantage of *Advanced Manufacturing Technology* is their ability to improve both production process and supply chain *Agility*. *AMT* can operate faster and efficiently and thus reduce cycle times (Singhry et al. 2016b). Recent studies have demonstrated that *AMT* implementation, especially in geographically isolated environments, can generate *Agility* and hence improve economic performance (Saliba et al. 2017). As Oberoi et al. (2007) argue, *AMT* first generates flexibility. It can be easily programmed, thereby allowing companies to expand product variety using the same machine. Then, flexible production leads to *Agility*—which is a valuable asset for companies—considering modern and sudden demand changes. That said, *AMT* investments could be expensive; moreover, estimation and management errors can even lead to bankruptcy. Therefore, authors usually suggest performing thorough analyses to confirm the feasibility and advantages of *AMT* implementation (Okure et al. 2006). In their work, Soltan and Mostafa (2015) claim that one of the sources of *Agility* in production processes is *AMT* integration. This claim is consistent with those findings reported by García Alcaraz et al. (2012), who affirm that a lack of appropriate manufacturing technology compromises agility, as production processes are not properly synchronized. Following this discussion on the relationship between *AMT* and *Agility* in supply chain systems, the second research hypothesis for this model can be proposed as follows:

H_2. *Advanced Manufacturing Technology* has a positive direct effect on supply chain *Agility*.

As a lean manufacturing practice, *Maintenance* programs offer attractive benefits for both corporations and supply chain systems. *Maintenance* programs ensure agile production processes, since they prevent unexpected machines stoppages (Soheilirad et al. 2017). In their research work, Gligor and Holcomb (2012) report that the main benefit of *Agility* is customer satisfaction, yet *Agility* must be ensured through appropriately maintained manufacturing technology. Similarly, Shaw et al. (2005) support the importance not only of lean manufacturing practices, but also of organizational culture and performance commitment. Likewise, Braunscheidel and Suresh (2009) point out that a lack of *Maintenance* programs is a source of risk in supply chain *Agility*. Therefore, authors such as Azevedo et al. (2012) and Vinodh et al. (2013) claim that a good *Maintenance* approach is essential in any supply chain *Agility* plan in the manufacturing industry. In this sense, the third research hypothesis for Model A can be proposed below:

H_3. *Maintenance* plans and programs have a positive direct effect on supply chain *Agility*.

The *Financial Performance* of a production system has many sources; one of them is the technological sophistication of manufacturing technology (Dubey and Gunasekaran 2015). In their work, Yang (2014) claim that *Agility* plans and programs always have to incorporate the possibility of investing in *Advanced Manufacturing Technology*. Nevertheless, as Singhry et al. (2016a) point out, there are always certain risks to take into account when incurring in such high costs, and if organizations fail to make the right decision, it can lead to bankruptcy. To avoid such a serious problem, Saberi and Yusuff (2012) recommend reviewing all the potential scenarios that might be the consequence of making this type of investments. For further information on the impact on *AMT* on corporate performance, consult the longitudinal analysis conducted by Boyer (1997), the study of Singhry et al. (2016a), and the work of Baldwin and Sabourin (2002). The latter performed a national study in Canada to report the benefits of *AMT* in the manufacturing industry. Following this discussion, it is possible to associate *AMT* and supply chain *Financial Performance* through the following research hypothesis:

H_4. *Advanced Manufacturing Technology* has a positive direct effect on supply chain *Financial Performance*.

If companies cannot make on time deliveries or lose production orders due to machine stoppages, their income will be affected (Cruz et al. 2014). Production tools and machinery that work in optimal conditions are a requisite for *Financial Performance*, since they give the production process necessary flexibility and allow companies to increase product variety. Authors such as Alqahtani and Gupta (2018) claim that *Maintenance* practices have guaranteed rewards, as the money invested in preserving machinery performance is rapidly recuperated in the form of sale profits. In fact, *Maintenance* practices and their relationship with corporate *Financial Performance* have been vastly analyzed in the healthcare sector (Shohet and Nobili 2016; Sénéchal 2016). Therefore, in the manufacturing industry, the following hypothesis can be proposed below:

H_5. *Maintenance* practices, plans and programs have a positive direct effect on corporate *Financial Performance*.

If *Agility* refers to the speed at which companies respond to customer needs, agile companies are easily accepted in the market and have a better *Financial Performance* (Gligor 2016). In his work, Um (2017) mentions that the relationship between these two variables is direct; that is, product customization has become a valuable characteristic for modern customers. However, García-Alcaraz et al. (2015) claim that production *Agility* is also the result of employee training. It is not a fortuitous benefit, as it depends on the overall efforts of human resources. On the other hand, Chan et al. (2017) analyzed the relationship between *Agility* and *Financial Performance* in the fashion industry and found a high trend in product customization and rapid deliveries. Furthermore, Gligor et al. (2015) claim that two important advantages of agile businesses are higher market coverage and greater customer acquisition, which consequently improve *Financial Performance*. In conclusion, *Agility* is a major source of business performance, especially in the manufacturing industry, as Yang (2014) state. Therefore, the final research hypothesis for Model A is proposed below:

H_6. Supply chain *Agility* has a positive direct effect on corporate *Financial Performance*.

15.1.2 Latent Variable Validation Process in Model A

All the latent variables explored in this model were already tested and validated in previous chapters. However, Table 15.1 introduces the validation results once more to contribute to a better understanding of the model. According to the R^2, adjusted R^2, and Q^2 values, the dependent latent variables have enough predictive validity from both parametric and nonparametric perspectives. Likewise, the values of the composite reliability coefficient and Cronbach's alpha—all higher than 0.7—confirm that all the latent variables have enough internal validity. Finally, the VIF coefficient proves that none of the latent variables has collinearity problems.

Table 15.1 Latent variable coefficients in Model A: *Manufacturing Practices–Benefits*

Coefficients	Financial performance	Advanced manufacturing technology	Agility	Maintenance
R-Squared (R^2)	0.273		0.328	0.401
Adjusted R^2	0.263		0.322	0.399
Composite reliability	0.837	0.869	0.909	0.897
Cronbach's alpha index (CAI)	0.705	0.773	0.874	0.827
Average variance extracted (AVE)	0.634	0.688	0.666	0.745
Full collinearity VIF	1.359	1.878	1.646	1.659
Q-Squared (Q^2)	0.277		0.326	0.402

15.1.3 Evaluation of Model A: **Manufacturing Practices–Benefits**

The model proposed in Fig. 15.1 was run once the latent variables were tested and validated as discussed in the methodology chapter. The results are illustrated in Fig. 15.2. As in previous models, the direct relationship or hypothesis is associated with a β value and a *P* value, being the former a measure of dependency and the latter an indicator of statistical significance.

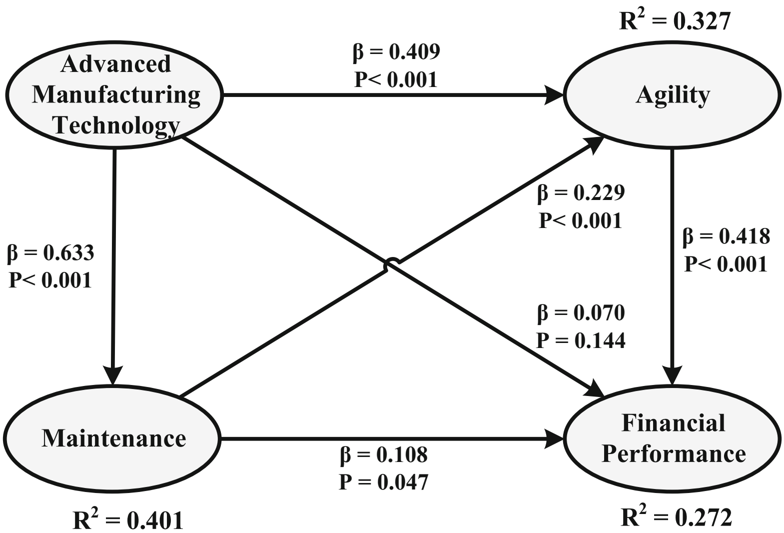

Fig. 15.2 Model A evaluated: *Manufacturing Practices–Benefits*

That is, relationships with a P value lower than 0.05 are statistically significant (at a 95% confidence level). Finally, each dependent latent variable in a relationship includes an R^2 value, that is, a measure of explained variance.

According to Fig. 15.2, it is possible to provide the following interpretations regarding the model:

- Five direct relationships or hypotheses are statistically significant, according to the P values, and only one is statistically non-significant.
- The dependent latent variables have enough predictive validity, according to the R^2 values (they are all higher than 0.02).

15.1.4 *Efficiency Indices in Model A*: Manufacturing Practices–Benefits

The model as a whole was tested by estimating the ten model fit and quality indices discussed in the methodology chapter. The test results are listed below:

- Average Path Coefficient (APC) = 0.311, $P < 0.001$
- Average R-Squared (R^2) (ARS) = 0.334, $P < 0.001$
- Average Adjusted R-Squared (AARS) = 0.328, $P < 0.001$
- Average block VIF (AVIF) = 1.521, acceptable if ≤ 5, ideally $\leq$ 3.3
- Average Full collinearity VIF (AFVIF) = 1.636, acceptable if ≤ 5, ideally ≤ 3.3
- Tenenhaus GoF (GoF) = 0.478, small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36
- Simpson's Paradox Ratio (SPR) = 1.000, acceptable if ≥ 0.7, ideally = 1
- R-Squared Contribution Ratio (RSCR) = 1.000, acceptable if ≥ 0.9, ideally = 1
- Statistical Suppression Ratio (SSR) = 1.000, acceptable if ≥ 0.7
- Nonlinear Bivariate Causality Direction Ratio (NLBCDR) = 1.000, acceptable if ≥ 0.7

The previous results fall into the intervals established by the Partial Least Squares (PLS) method and thus confirm that the model has a good fit and efficiency. Therefore, the model can be interpreted accordingly.

15.1.5 *Direct Effects*

According to Fig. 15.2, and following the model test results, the following conclusions can be proposed regarding the research hypotheses or direct relationships between the latent variables:

H_1. There is enough statistical evidence to claim that *Advanced Manufacturing Technology* has a positive direct effect on *Maintenance* programs implemented for

production machinery. When the first latent variable increases by one standard deviation, the second latent variable increases by 0.633 standard deviations.
H_2. There is enough statistical evidence to claim that *Advanced Manufacturing Technology* has a positive direct effect on supply chain *Agility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.409 standard deviations.
H_3. There is enough statistical evidence to claim that machinery *Maintenance* programs have a positive direct effect on supply chain *Agility*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.229 standard deviations.
H_4. There is not enough statistical evidence to claim that *Advanced Manufacturing Technology* has a positive direct effect on corporate *Financial Performance*, since the *P* value associated with this relationship is higher than 0.05.
H_5. There is enough statistical evidence to claim that *Maintenance* programs have a positive direct effect on corporate *Financial Performance*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.108 standard deviations.
H_6. There is enough statistical evidence to claim that supply chain *Agility* has a positive direct effect on corporate *Financial Performance*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.418 standard deviations.

15.1.6 Effect Sizes

As a coefficient, R^2 indicates the variability of a dependent latent variable, which is due to the influence of one or more independent latent variables. If two or more independent variables explain the variability of a dependent latent variable, the value of the R^2 coefficient must be decomposed to determine which independent factor influences more the dependent factor. Each portion of explained variance is known as an effect size. Table 15.2 summarizes the effect sizes for Model A.

Table 15.2 Effect sizes in Model A

To	From			R^2
	Advanced manufacturing technology	Agility	Maintenance	
Financial performance	0.024	0.211	0.037	0.272
Agility	0.221		0.106	0.327
Maintenance	0.401			0.401

According to the results summarized above, the following interpretations are introduced:

- The direct effect from *Advanced Manufacturing Technology* to *Economic Performance* is not significant. Moreover, the contribution of the former to the variability of the latter is merely 2.4%. However, the indirect relationship between these two latent variables will be discussed later.
- Thanks to *Manufacturing Practices*, supply chain *Agility* has the largest effect size on *Financial Performance*.
- *Advanced Manufacturing Technology* has the largest effect size, and thus the largest influence, on *Agility*. In other words, technologically sophisticated companies are more agile and can respond faster to customer needs. Similarly, the influence of *Maintenance* programs on *Agility* is moderate, yet it indicates that machines that operate in optimal conditions ensure material flow and thus improve delivery performance.

15.1.7 Sum of Indirect Effects

Latent variables can be indirectly related through mediator variables, and they are usually discussed with respect to the indirect effects that they generate. Graphically, indirect relationships can be tracked by following two or more model segments. Table 15.3 summarizes the effects found in the indirect relationships of Model A.

The indirect relationship between *Advanced Manufacturing Technology* and *Financial Performance* has significant effects, yet the direct relationship was statistically not significant. As Table 15.3 summarizes, the impact of *AMT* on *Financial Performance* can only be ensured through *Agility* and machinery *Maintenance*. As for the indirect relationship between *Advanced Manufacturing Technology* and *Agility*, it is feasible thanks to the presence of *Maintenance* programs as the mediator variable. In other words, preserving machinery performance improves material flow by preventing unexpected production disruptions.

Table 15.3 Sum of indirect effects in Model A

To	From	
	Advanced manufacturing technology	Maintenance
Financial performance	0.300 ($P < 0.001$) ES = 0.104	0.096 ($P = 0.020$) ES = 0.033
Agility	0.145 ($P < 0.001$) ES = 0.078	

15.1.8 Total Effects

In SEM, total effects are estimated to provide a holistic view on the relationships among latent variables. If they are comprehensively interpreted, some relationships can be truly significant in spite of having either direct or indirect effects that are not statistically significant. In this sense, Table 15.4 summarizes the total effects estimated for the relationships between the latent variables in Model A.

- The relationship between *Advanced Manufacturing Technology* and *Maintenance* has the largest total effects. Nevertheless, these are merely the result of the direct relationship between the two latent variables, as no indirect effects were found.
- The relationship between *Advanced Manufacturing Technology* and *Agility* reports the second largest total effects. Latent variable *Maintenance* plays a crucial role in this relationship as the mediator variable.
- In the relationship between *Advanced Manufacturing Technology* and *Financial Performance*, no significant direct effects were found. However, this relationship is significant when analyzing the total effects thanks to the influence of both *Maintenance* and *Agility*.

15.1.9 *Conclusions and Industrial Implications for Model A:* Manufacturing Practices–Benefits

This model explores the relationships between two *Manufacturing Practices* (i.e., *Advanced Manufacturing Technology* and *Maintenance*) and two supply chain performance benefits (*Agility* and *Financial Performance*). To contribute to a holistic understanding of these relationships, the following remarks are proposed:

- *Advanced Manufacturing Technology* has often been associated with increased *Financial Performance.* Nevertheless, this research found that the direct

Table 15.4 Total effects in Model A

To	From		
	Advanced manufacturing technology	Agility	Maintenance
Financial performance	0.370 ($P < 0.001$) ES = 0.128	0.418 ($P < 0.001$) ES = 0.211	0.203 ($P < 0.001$) ES = 0.070
Agility	0.554 ($P < 0.001$) ES = 0.300		
Maintenance	0.633 ($P < 0.001$) ES = 0.401		0.229 ($P < 0.001$) ES = 0.106

relationship between these two variables is not significant. Instead, it is guaranteed thanks to the role of appropriate *Maintenance* programs and the ability of companies to manage the supply chain with *Agility*. In the manufacturing industry, such results imply that *AMT* support programs must come along with adequate preventive, predictive, and total maintenance programs. Undoubtedly, investing in *AMT* without thorough analyses or without providing it with proper maintenance is a serious mistake.

- *Advanced Manufacturing Technology* is important only if it is provided with appropriate *Maintenance*. *AMT* sensors and systems can promptly prevent or warn of potential failures and thus help ensure an appropriate flow of material by preventing unexpected stoppages and thus production disruptions. Likewise, modern manufacturing technology relies on friendly interfaces that support man–machine interaction.
- Undoubtedly, the manufacturing industries surveyed in this research work gain important *Benefits* by implementing *Advanced Manufacturing Technology* that is operated by a qualified workforce. These companies focus on generating greater *Agility* and speed while ensuring the material's flow thanks to the implementation of machinery *Maintenance* programs.
- The direct relationship between *Maintenance* programs *and Financial Performance* is not significant, yet the influence of *Agility* has a statistically significant effect. Such results imply that when production technology operates in optimal conditions, supply chain *Agility* increases as well as customer satisfaction. Consequently, companies earn more profits.

15.2 Model B: Manufacturing Practices–Benefits

This model analyzes the interactions between two different manufacturing practices and two supply chain performance benefits. Namely, the model analyzes the relationships between the following latent variables:

Manufacturing practices:

- *Total Quality Management* (3 items or observed variables)
- *Just in Time* (2 items or observed variables)

Supply chain performance benefits:

- *Delivery Times* (2 items or observed variables)
- *Customer Service* (3 items or observed variables)

For further information on the observed variables that constitute these latent variables, please consult the survey sample found in the appendix section.

15.2.1 Hypotheses Formulation: Model B

This model is composed of four latent variables, which in total comprise ten observed variables. The goal is to demonstrate that manufacturing practices associated with production quality can improve customer service performance. The six hypotheses associating the latent variables are depicted in Fig. 15.3 and will be discussed in the paragraphs afterward.

The first research hypothesis proposed in this model was first tested and validated in the previous chapter (see H_5 Fig. 14.7). Therefore, it is not thoroughly discussed in this section. However, as a reminder, the hypothesis reads as follows:

H_1. *Total Quality Management* tools and practices have a positive direct effect on *Just in Time* implementation.

The impact of *Total Quality Management* on *Just in Time* implementation has been widely studied. In the decade of 1990, Withers et al. (1997) reported a study conducted among 500 American manufacturing companies ascribed to the ISO 9000 norm and found that they all complied with their working contracts. Later on, Cua et al. (2001) found a relationship between *Total Quality Management* and *Just in Time* systems that included maintenance and performance programs, whereas Ahmad et al. (2012) explored the same relationship but with respect to production process tools, such as statistical quality control. From a similar perspective, Bolatan et al. (2016) discussed the impact of quality planning on *Delivery Times* and highlighted that the extent to which a product is manufactured correctly and delivered on time depends on the technological sophistication of the company. However, as Zehir et al. (2012), it is important to assess more corporate and supply chain performance indices to ensure successful *Total Quality Management*. For further information on the benefits of quality programs and quality success factors,

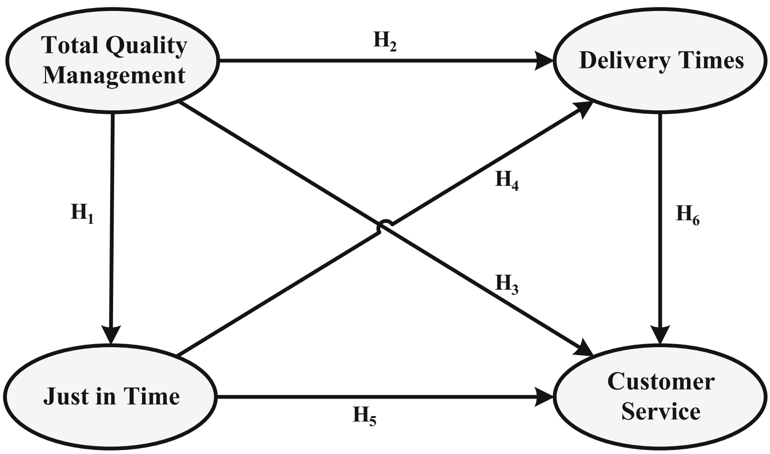

Fig. 15.3 Model B proposed: *Manufacturing Practices–Benefits*

consult the list provided by Kannan and Tan (2005) and the work of Suwandej (2015), respectively. Following this discussion, it is possible to propose the second research hypothesis for Model B as follows:

H_2. *Total Quality Management* tools and practices have a positive direct effect on *Delivery Times.*

Traditionally, *Just in Time* is seen as a philosophy whose goal is to reduce inventory levels along the supply chain, and consequently, to make a difference in terms of product *Delivery Times* (Panuwatwanich and Nguyen 2017). In their work, Green et al. (2014) report the impact of *Just in Time* and its relationship with supply chain management strategies. The structural equation models developed by the authors include *Delivery Times* as one of the response variables. From a similar perspective, Wu et al. (2013) claim that *Just in Time* is a risk mitigation strategy that guarantees *Delivery Times* in supply chain systems. In this sense, experts posit that *Delivery Times* must be considered as a primary performance indicator in supply chain systems (Kojima et al. 2008).

In their work, Alcaraz et al. (2016) conducted a factor analysis of 31 JIT benefits and found inventory management performance and *Delivery Times* as the most important. Such findings are consistent with those reported by Phan and Matsui (2010); however, it is important to mention that *Just in Time* does not operate as an isolated system. The philosophy rather relies on many other production technologies, techniques, and approaches to meet its goals, such as Kanban for *Delivery Times* (Sendil Kumar and Panneerselvam 2007). To explore the relationship between both *Just in Time* and *Delivery Times*, the third research hypothesis for Model B states as follows:

H_3. *Just in Time* implementation in production systems has a positive direct effect on product *Delivery Times*.

Two of the main reasons why companies implement *Total Quality Management* systems are to improve *Customer Service* and preserve customer loyalty; that is, quality must be customer-focused (Agus and Hassan 2011). However, Moosa et al. (2010) conducted a research work among Pakistani industries and concluded that implementing *Total Quality Management* systems is not always an easy task, as it involves multiple cultural and organizational aspects. Similarly, it has been discovered that even though organizations do not always obtain the desired benefits, quality programs are always a business strategy, especially among sectors where *Customer Service* is vital, such as the fast-food industry (Kanyan et al. 2016).

Total Quality Management can improve *Customer Service* but depends on trained human resources that provide customers the right information. In this sense, customer-focused employee education and training is essential (Mahmud and Hilmi 2014). Finally, it is important to mention that the goal of *Customer Service* is only to guide customers on product use and handling and must not be seen as a way to respond to complaints. If a product has the right quality, and quality plans and programs operate properly, then, product complains should not exist (Kiran 2017).

To explore the relationship between *Total Quality Management* and *Customer Service* in the manufacturing industry, the fourth research hypothesis of Model B states as follows:

H_4. *Total Quality Management* tools and practices have a positive direct effect on *Customer Service* performance.

Informed customers demand unique and high-quality products that do not cost much and can be delivered rapidly (Amasaka 2014); however, to this end, multiple production strategies and tools are necessary. *Just in Time* is one of these tools, as it guarantees that customers receive what they purchased in the right amount and as quickly as possible, as promised by the company (Rodríguez-Méndez et al. 2015). Alcaraz et al. (2016) found that the major short-term benefit of *Just in Time* implementation was improved *Customer Service*. However, as any production philosophy, *JIT* depends on appropriate employee training, skills, and knowledge (García-Alcaraz et al. 2015) to translate its operations into higher customer satisfaction, increased sales, and greater financial performance (Balakrishnan et al. 1996; Montes 2014). For those readers willing to explore further *JIT* elements, benefits, and implementation barriers, we recommend the research work of Singh and Garg (2011). Following this discussion, it is possible to propose the fifth working hypothesis for Model B below:

H_5. *Just in Time* implementation in production systems has a positive direct effect on *Customer Service* performance.

Timely, orderly, and quality deliveries promote customer loyalty (Ding-fu and Li 2011). Even though the relationship between *Delivery Times* and *Customer Service* is more often explored in the services sector, multiple research works study it in the manufacturing industry (Rod et al. 2016). For instance, Yu et al. (2015) conducted a research work in the Chinese manufacturing industry, where customers are fully informed of product characteristics and can rapidly file complaints to manufacturers. On the other hand, as regards the services sector, Farooq et al. (2018) analyzed the case of Malaysian airlines through a structural equation model to determine the effects of *Delivery Times* on *Customer Service*. Meanwhile, Lynn and Brewster (2018) and Alhelalat et al. (2017) explored the same relationship in the restaurant industry. Finally, Holtom and Burch (2016) analyzed customer behavior during unpunctual deliveries, while Liu et al. (2006) analyzed the costs of uncompleted orders and potential customer loss. In this sense, the sixth research hypothesis for Model B states as follows:

H_6. Punctual *Delivery Times* have a positive direct effect on *Customer Service* performance.

15.2.2 *Latent Variable Validation Process of Model B*

Most of the latent variables comprised in this model were first tested and validated in previous chapters, yet they must be analyzed once more with respect to their new relationships to determine their predictive validity in this particular model. Table 15.5 reports the latent variable coefficients estimated as discussed in the methodology chapter. According to these results, all the latent variables meet the validity criteria. In other words, the dependent latent variables have adequate predictive validity from both parametric and nonparametric perspectives; the VIF coefficient confirms that none of the latent variables has collinearity problems, whereas both the CAI and the composite reliability index indicate adequate internal validity. Finally, according to AVE, all the latent variables have acceptable convergent validity.

15.2.3 *Evaluation of Model B:* Manufacturing Practices–Benefits

Once the latent variables were tested, the model was run as described in the methodology chapter. Figure 15.4 illustrates the tested model. Each hypothesized relationship includes two values: a β value and a P value. The former is a measure of dependency, whereas the latter is an indicator of statistical significance. Relationships with a P value lower than 0.05 are statistically significant. Similarly, the dependent latent variable of each relationship includes an R^2 value as a measure of explained variance.

Table 15.5 Latent variable coefficients in Model B: *Manufacturing Practices–Benefits*

Coefficients	Customer service	Total quality management	Delivery times	Just in time
R-Squared (R^2)	0.316		0.329	0.375
Adjusted R^2	0.307		0.323	0.373
Composite reliability	0.857	0.911	0.840	0.858
Cronbach's alpha index (CAI)	0.750	0.854	0.618	0.670
Average variance extracted (AVE)	0.667	0.774	0.724	0.752
Full collinearity VIF	1.439	1.701	1.709	1.824
Q-Squared (Q^2)	0.319		0.333	0.375

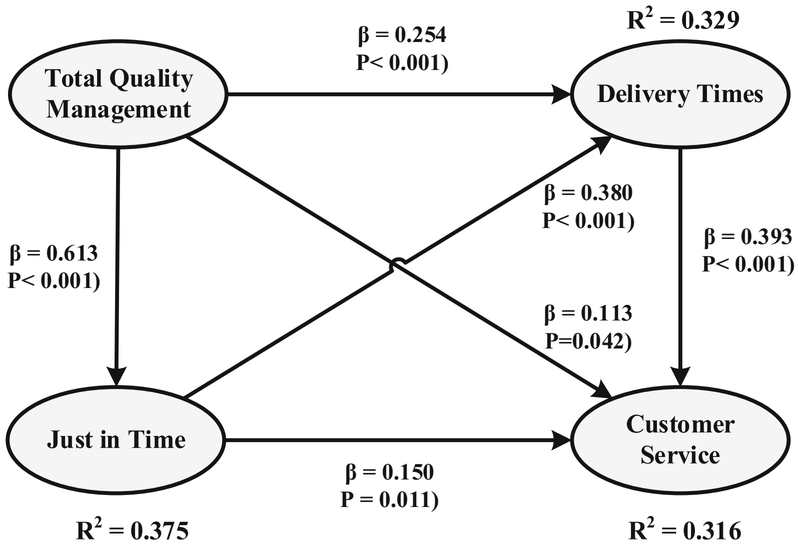

Fig. 15.4 Model B evaluated: *Manufacturing Practices–Benefits*

15.2.4 Efficiency Indices in Model B: **Manufacturing Practices–Benefits**

As in previous sections, the model must be evaluated as a whole to determine its efficiency and quality. The ten model fit and quality indices estimated according to the methodology chapter are listed below:

- Average Path Coefficient (APC) = 0.317, $P < 0.001$
- Average R-Squared (ARS) = 0.340, $P < 0.001$
- Average Adjusted R-Squared (AARS) = 0.334, $P < 0.001$
- Average block VIF (AVIF) = 1.681, acceptable if ≤ 5, ideally ≤ 3.3
- Average Full collinearity VIF (AFVIF) = 1.668, acceptable if ≤ 5, ideally ≤ 3.3
- Tenenhaus GoF (GoF) = 0.498, small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36
- Simpson's Paradox Ratio (SPR) = 1.000, acceptable if ≥ 0.7, ideally = 1
- R-Squared Contribution Ratio (RSCR) = 1.000, acceptable if ≥ 0.9, ideally = 1
- Statistical Suppression Ratio (SSR) = 1.000, acceptable if ≥ 0.7
- Nonlinear Bivariate Causality Direction Ratio (NLBCDR) = 1.000, acceptable if ≥ 0.7

According to the values of ARS and AARS, the model has adequate predictive validity. Moreover, APC indicates that the hypothesized relationships are adequate. As for the AVIF and AFVIF, they confirm that the model is free from collinearity problems. The Tenenhaus GoF indicates a good model fit and thus implies that the information collected in this research is consistent with the model results. The model as a whole can now be interpreted accordingly.

15.2.5 Direct Effects

This section validates the hypothesized relationships proposed in Fig. 15.3 according to the results of the model tested in Fig. 15.4. The following conclusions can be proposed:

H_1. There is enough statistical evidence to claim that *Total Quality Management* tools and practices have a positive direct effect on *Just in Time* implementation, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.613 standard deviations.
H_2. There is enough statistical evidence to claim that *Total Quality Management* tools and practices have a positive direct effect on *Delivery Times*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.254 standard deviations.
H_3. There is enough statistical evidence to claim that *Just in Time* implementation in production systems has a positive direct effect on product *Delivery Times*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.380 standard deviations.
H_4. There is enough statistical evidence to claim that *Total Quality Management* tools and practices have a positive direct effect on *Customer Service* performance, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.113 standard deviations.
H_5. There is enough statistical evidence to claim that *Just in Time* implementation in production systems has a positive direct effect on *Customer Service* performance, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.150 standard deviations.
H_6. There is enough statistical evidence to claim that *Delivery Times* have a positive direct effect on *Customer Service* performance, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.393 standard deviations.

15.2.6 Effect Sizes

Since in this model the variability of the dependent latent variables is explained by multiple independent latent variables, Table 15.6 reports the effect sizes found in the indirect relationships. According to these results, it is possible to conclude the following:

Table 15.6 Effect sizes in Model B

To	From			R^2
	Total quality management	Delivery times	Just in time	
Customer service	0.045	0.207	0.064	0.316
Delivery times	0.125		0.204	0.329
Just in time	0.375			0.375

- Latent variable *Delivery Times* has the most important influence on *Customer Service* performance. The effect size from this independent variable is the largest if compared to the effect sizes from the other latent variables that influence *Customer Service*. In addition, this is a direct effect, as no mediator variables are included in this relationship.
- *Just in Time* implementation explains 32.9% of the variability of *Delivery Times*, whereas *Total Quality Management* explains 20.4%. In other words, *Just in Time* is the most important element for *Delivery Times* with respect to *Total Quality Management* and that has a common sense, because JIT philosophy is aimed to reduce late *Delivery Times* and currently there is a lot of literature indicating that phenomenon.
- Only *Total Quality Management* can explain the variability of *Just in Time*. Therefore, the R^2 value associated with the dependent latent variable is not decomposed.

15.2.7 Sum of Indirect Effects

As mentioned in the previous paragraphs, and as depicted in Fig. 15.4, the two supply chain benefits are explained by multiple independent latent variables. Table 15.7 reports the sum of indirect effects in the model.

According to the estimations summarized in the table, the following conclusions can be proposed:

- The indirect relationship between *Total Quality Management* and *Customer Service* has the largest effects, unlike the direct relationship, whose effects were barely significant and with a value of 0.113. Such results imply that quality

Table 15.7 Sum of indirect effects in Model B

To	From	
	Total quality management	Just in time
Customer service	0.283 ($P < 0.001$) ES = 0.112	0.149 ($P = 0.047$) ES = 0.064
Delivery times	0.233 ($P < 0.001$) ES = 0.114	

programs and plans alone do not guarantee appropriate *Customer Service* performance. Additionally, companies must rely on a *Just in Time* approach to visualize their efforts in delivery performance.
- *Just in Time* implementation plays a crucial role in the relationship between *Total Quality Management* and *Delivery Times*. The effects of this indirect relationship are equal to 0.233, whereas the effects found in the direct relationship equal 0.254. Since both values are similar, we confirm our previous claim that quality programs and plans are useless without a *Just in Time* system
- Finally, this model demonstrates that *Just in Time* improves *Customer Service* performance only if it has an impact on *Delivery Times*. The effects of the direct relationship are equal to 0.150, whereas those estimated in the indirect relationship equal 0.149.

15.2.8 Total Effects

In SEM, total effects are estimated to provide a holistic view on the interrelations among latent variables. If they are totally interpreted, some relationships can be truly significant in spite of having either direct or indirect effects that are not statistically significant. Table 15.8 summarizes the total effects estimated in the model's relationships.

According to these results, the following conclusions can be proposed:

- Overall, the effects of *Total Quality Management* on the other latent variables have the highest values. These findings demonstrate the importance of quality programs and systems in supply chain performance.
- The relationship between *Total Quality Management* and *Just in Time* has the largest total effects. These effects correspond to the direct relationship between both variables, as none mediator variable seems to influence. Such results imply that *Total Quality Management* is vital for successful *JIT* programs. In other words, any *JIT* approach must be part of a well-established quality program and system.

Table 15.8 Total effects in Model B: *Manufacturing Practices–Benefits*

To	From		
	Total quality management	Delivery times	Just in time
Customer service	0.397 ($P < 0.001$) ES = 0.158	0.393 ($P < 0.001$) ES = 0.207	0.299 ($P < 0.001$) ES = 0.129
Delivery times	0.487 ($P < 0.001$) ES = 0.239		0.380 ($P < 0.001$) ES = 0.204
Just in time	0.613 ($P < 0.001$) ES = 0.375		

- In the relationship between *Total Quality Management* and *Delivery Times*, *Just in Time* implementation plays a crucial role. The effects of the direct relationship between the two first variables show $\beta = 0.254$, whereas the indirect effect reports $\beta = 0.233$. The total effects consequently report $\beta = 0.487$.
- The relationship between *Total Quality Management* and *Customer Performance* has total effects that equal 0.397. In this relationship, *Just in Time* and *Delivery Times* play a vital role in *Customer Performance*, as they significantly contribute to the total effect. Such results imply that quality plans and programs must rely on an appropriate *JIT* system and punctual *Delivery Times* if companies are willing to improve their *Customer Service* performance.

15.2.9 Conclusions and General Implications for Model B: **Manufacturing Practices–Benefits**

This model explores the interactions among two *Manufacturing Practices* and two supply chain performance *Benefits* as performance metrics. The model developed six research hypotheses from which the following conclusions and industrial implications can be proposed:

- Quality plans and programs implemented in production systems do not guarantee *Customer Service* performance by themselves. Companies must rely on continuous material and production flow as well as on an adequate *Just in Time* system that guarantees on time deliveries. This claim is consistent with the principle of the *Just in Time* philosophy, which is to produce only what is necessary, when it is necessary, and in the right amount. Such a manufacturing approach allows companies to meet established delivery times while simultaneously adhering only to existent demand requirements.
- Any *Just in Time* approach must aim at complying with *Delivery Times* in order to have a positive impact on *Customer Service.* This claim is supported by the high value of the effect found in the indirect relationship between *Just in Time* and *Customer Service* thanks to the presence of *Delivery Times.* That said, the first two latent variables also have a direct relationship. Such results imply that manufacturing companies must deliver complete orders on time to customers, while simultaneously responding to variables such as costs and flexibility.
- Finally, the findings in this section imply that the manufacturing companies surveyed in this book appropriately implement the four major manufacturing practices (i.e., *Just in Time*, *Total Quality Management*, *Advanced Manufacturing Technology*, and *Maintenance* programs). This claim is supported by the values of the Tenenhaus GoF obtained in the two previous models. Moreover, the explained variance values are remarkably high.

15.3 Integrative Model (Regional Factors–Risks Factors–Manufacturing Practices–Supply Chain Performance)

This book has explored the relationships between three major impact factors or groups of variables—*Regional Factors*, *Risk Factors*, *and Manufacturing Practices*—and supply chain performance *Benefits*. However, until now, these analyses have been performed individually. The model presented in this section is an integrative construct where each previously analyzed latent variable becomes an observed variable that is part of a much larger category. The goal of this new model is not only to holistically explore how the three major impact factors have an impact on *Supply Chain Performance*, but also to determine how they are interrelated and influence on one another.

The model allows us to discover, for instance, how *Manufacturing Practices* have an impact on supply chain performance benefits, or how *Regional Factors* can affect the perception of supply chain *Risks Factors*. Finally, the model assumes that *Regional Factors* have an influence on all the remaining latent variables, and that *Supply Chain Performance* is the ultimate outcome of manufacturing companies. Under this premise, the former is considered as the independent or initial latent variable, whereas the latter is the final variable. The four latent variables of this model are listed below along with their corresponding observed variables:

- *Risks Factors* (3 items or observed variables)
  - Supply Risks
  - Production Process Risk
  - Demand Risks
- *Regional Factors* (7 items or observed variables)
  - Regional Infrastructure
  - Regional Costs
  - Services
  - Government
  - Quality of Life
  - Proximity
  - Workforce
- *Manufacturing Practices* (4 items or observed variables)
  - Total Quality Management
  - Just in Time
  - Maintenance
  - Advanced Manufacturing Technology

- *Supply Chain Performance* or benefits (8 items or observed variables)
  - Delivery Times
  - Quality
  - Flexibility
  - Customer Service
  - Agility
  - Financial Performance
  - Inventory
  - Transportation

For further information on the observed variables comprised in the latent variables, please consult the sample survey in the appendix section.

15.3.1 Hypotheses in the Integrative Model

The model integrates four latent variables that are related thanks to six research hypotheses. Figure 15.5 illustrates this initial model. As previously mentioned, this is an integrative second-order model.

Regional Factors are often viewed as critical competitiveness elements (Avelar-Sosa et al. 2014; Bhatnagar and Sohal 2005; Jaimurzina et al. 2015; Porter 2011; Camagni 2017). For instance, authors Duggal et al. (2007) claim that *Regional Impact Factors*, such as employee education, either improve or hinder corporate productivity. The authors concluded that highly industrialized cities that rely on a highly qualified workforce can easily find appropriate economies and

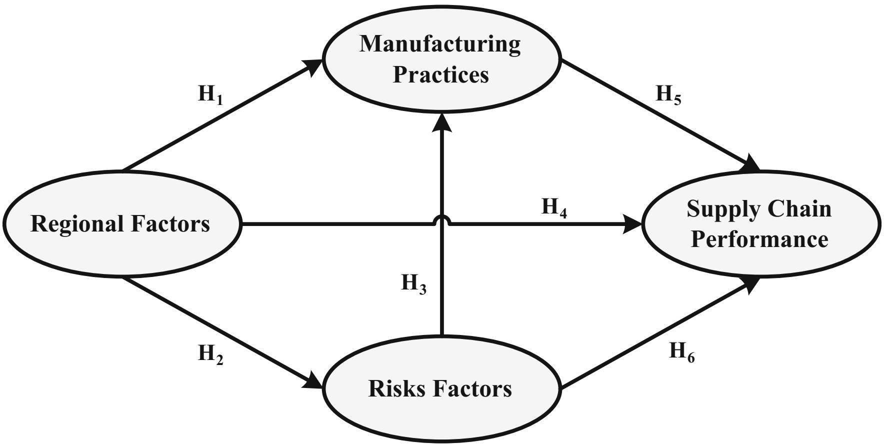

Fig. 15.5 Integrative model proposed: *Regional Factors–Risks Factors–Manufacturing Practices–Supply Chain Performance*

market relationships. On the other hand, transportation and telecommunication services have proven to facilitate technological innovation and reduce costs while simultaneously increasing productivity (Agénor 2013).

Additionally, technology and information infrastructure contributes to increased production; therefore, a lack of it can affect productivity levels (Duggal et al. 2007). On the other hand, energy supply networks represent important manufacturing costs (Tate et al. 2014), and thus must play a role in company location. Similarly, transportation services allow companies to increase operation margins thanks to efficient transportation systems and better communication networks (Jaimurzina and Sánchez 2017; Jaimurzina et al. 2015).

In their work, Vinodh and Joy (2012) claim that productivity does not depend on a cheap workforce and high batches, but rather on skilled employees and creativity in order to manufacture complex products that meet high technological specifications. Likewise, advanced manufacturing technology includes multiple knowledge areas and specialties. For instance, big data improve demand forecast, while advanced sensors improve control measures and processes, advanced materials design, synthesis and processing. In this sense, a lack of policies that support science, technology, and innovation is an obstacle for productivity, competitiveness, and development in Mexico. In other words, the country requires strategic decision making that promotes integration and coordination between actors and institutions in order to avoid dissipating efforts and spraying public resources (Dutrénit 2015).

Increasing productivity also demands the availability of logistic networks to respond to and adapt dynamically to emergent competitive and sustainability criteria, and also attract demand. Appropriate infrastructure availability, along with efficient logistic services, improves productivity and generates competitive advantages. These aspects are two of the most important in development policies (Sánchez and Gómez Paz 2017) for manufacturing companies. Finally, as Calderon and Servén (2014) claim, governments provide the necessary regional infrastructure, education programs, and health care to encourage the development of competitive strategies in the manufacturing industry. In this sense, the expansion of infrastructure services reduces inequality in professional opportunities, increases return on investments, and increases employment opportunities in less favored social sectors. Following this discussion, the first research hypothesis for the integrative model states as follows:

H_1. In the manufacturing industry, *Regional Factors* have a positive direct effect on *Manufacturing Practices*.

Unexpected situations are sources of supply chain risks that might ultimately translate into big economic losses if companies do not have the necessary tools and plans to tackle them (Cedillo-Campos et al. 2017). Some authors advise companies to develop risk mitigation norms to increase operational safety (Parra Silva 2017). Since modern supply chain systems are highly globalized and interconnected, they usually face risks and problems due to a lack of regional or national infrastructure in border regions (Perez et al. 2010). In order to develop risk mitigation strategies, supply chain systems must rely on governmental support. Governments must establish regulations and initiatives that improve supply chain safety, especially in the manufacturing industry, as Johansson (2008) claim. Similarly, political cooperation and interaction are necessary among those countries involved in the market network. This would allow businesses to secure the flow of products, minimize costs (Bronk and González-Aréchiga 2011), and improve delivery times (Duran-Fernandez and Santos 2014).

Transportation infrastructure is vital for the correct functioning of logistic operations and economic competitiveness. Multiple studies highlight the notorious correlation between (a) the quality of transportation infrastructure and logistics and (b) market development and economic performance (Francois and Manchin 2013; Becerril-Torres et al. 2010; Hochman et al. 2013; Duran-Fernandez and Santos 2014). Likewise, it has been argued that infrastructure investments allow companies to be more productive and increase international competitiveness. On the other hand, other researchers consider that workforce and technology are fundamental (Brock and German-Soto 2013).

In conclusion, supply chain risks are rarely easy to diminish. Risk mitigation requires more than just risk identification. Companies must also consider the potential damages of such kind of risks and ought to implement efficient mitigation programs that consider their immediate environment, including government policies, available services, infrastructure costs, and labor costs, among others. Following this discussion, the second research hypothesis of the integrative model is proposed below:

H_2. In the manufacturing industry, *Regional Factors* have a negative direct effect on the perception of supply chain *Risks Factors*.

Production process risks can be defined as potential deviations from pre-established production plans that compromise both quality and delivery times (Koufteros et al. 2014). Uncertainty in cycle times or in new product development leads to serious risks as much as supply or demand changes do. Unfortunately, such changes compromise the stability and reliability of the production process. Some authors claim that high levels of external uncertainty (i.e., demand and supply uncertainty) affect the perceived level of risk in the production process (Sreedevi and Saranga 2017) and thus compromise productivity in the manufacturing industry. Similarly, it has been claimed that sudden demand change originates changes in supply and hence increases the likelihood of uncompleted supply deliveries (Khanchanapong et al. 2014).

The literature suggests important aspects for supply chain resilience amid potential external and internal risks (Blos et al. 2015). Some of these aspects include customer service, inventory management, flexibility, commercialization times, financial support, cycle times, quality, and market proximity. These aspects have the potential to increase supply chain efficiency and mitigate the likelihood of risks in demand, supply, or even in the production process. However, these elements must be supported by the five-lean-principle approach of value, value stream, flow, pull, and perfection (Womack and Jones 2005; Perez et al. 2010). In this sense, the third research hypothesis can be proposed below:

H_3. In the manufacturing industry, external and internal supply chain *Risks Factors* have a negative direct effect on *Manufacturing Practices*.

Governance includes all those actors that are directly or indirectly part of an activity: the government, the industry, employees, communities, the society, and the natural environment (Altomonte and Sánchez 2016). Multiple research works have studied governmental participation in regional economic development with respect to corporate competitiveness across regions (Bhatnagar and Sohal 2005). Some authors found that public policies that define legal work contracts thus have an impact on employee flexibility, and consequently on corporate productivity. Likewise, governmental changes due to elections or other political motives can generate uncertainty (Sreedevi and Saranga 2017) that might be difficult to mitigate (Chatzikontidou et al. 2017).

According to Sendlhofer and Lernborg (2017), governments are primarily responsible for providing and supporting educational systems and services across their territories to ensure a highly skilled and qualified workforce. In this sense, employee education, skills, and multifunctional capabilities can increase corporate flexibility.

Ríos (2016) claims that production adjustments must be performed always by considering green and environmental aspects that simultaneously increase business profitability and investments. Similarly, companies must take into account technological development, costs of inputs, transportation, financing, workforce quality, regional demand, and market location. Manyika (2012) claims that the most important factors in the manufacturing industry are a low-cost skilled workforce, market proximity, effective transportation and infrastructure, input availability, energy supply, and proximity to innovation areas. These elements represent important areas of research to be explored with respect to global production among companies.

In the context of Latin America, Ríos (2016) explored critical development factors and concluded that a high-quality infrastructure has an important impact on development. On the one hand, it favors physical connectivity and thus promotes market activities, increases productivity, and reduces transportation timing. On the other hand, regional infrastructure has a social impact as it provides access to public services. Finally, Ríos (2016) claims that in order to achieve production transformation, it is important to close the infrastructure–logistics gap, improve quality in education at all levels, and promote innovation, research, and development.

Governments are also responsible for transportation infrastructure, such as roads and ports, and for establishing the necessary regulations to maintain this infrastructure in optimal conditions (Kogan and Tapiero 2011). Low-quality or deficient transportation systems, services, and infrastructure delay the distribution. Sometimes such deficiencies are due to a lack of appropriate governmental administration and unfortunately compromise export activities in the region, which in turn affect foreign investment and economic development (Bayer et al. 2009).

Government policies must be conditioned to productivity results (ONU 2015). As experts argue, in Latin America a solid strategy is necessary to promote a long-term common vision on infrastructure governance (Nieto 2017). This strategy would be essential for the transformation of current infrastructure services under a futuristic view. Moreover, countries need to take advantage of the integration of regional economic infrastructures to offer more resilient and cheaper sub-regional services and products of a network economy and with scope. Likewise, as Jaimurzina and Sánchez (2017) and Nieto (2017) point out, it is important to promote the implementation of logistics and mobility policies for transportation.

Finally, value chains can be affected by multiple external problems associated with natural resources, water supply, safety and health, work conditions, and work inequality, among others (Porter and Kramer 2019). Opportunities for generating value in companies emerge thanks to these problems; that is, they can become serious economic difficulties, such as increased supply chain costs. In this sense, externalities do have an impact on internal costs, even though companies pay preferential taxes on materials and inputs or have some type of governmental support. On the other hand, there seems to be a high correlation between competitiveness and the physical flow of goods. Therefore, the competitiveness of economies might be benefitted when a region offers integrated policies for infrastructure, transportation, and logistics (Cipoletta Tomassian et al. 2010).

As regards the position of the Mexican government with respect to international development, the 2030 Agenda identifies five barriers to national sustainable development: (a) market rigidity, (b) informal incentives that cause productivity stagnation, (c) lack of greater competition and innovation, (d) scarcity of human capital, and (e) excess of institutional failures (Nieto 2017). Under such premises, and considering the importance of Mexico's economic development through the manufacturing industry, the following hypothesis can be proposed:

H_4. In the manufacturing industry, *Regional Factors* have a positive direct effect on supply chain *Performance*.

Lean manufacturing practices have been adopted for decades by companies around the world in order to add as much value as possible to products and thus generate profits (Vokurka et al. 2007). Some authors have found that lean manufacturing practices improve the management of production flows, production processes, human resources, and supplier relationships (Matsui 2007; Swink et al. 2005), whereas others claim that, for instance, JIT allows companies to improve delivery times, even for small batches, reduce inventory levels, and minimize costs (Prajogo and Olhager 2012). In their work, Schoenherr and Swink (2012) confirm that companies can gain significant benefits when they employ interconnected strategies for supply chain alignment. In other words, it is possible to reduce uncertainty at the manufacturing, planning, procurement, and logistics stages when

JIT is implemented. The benefits will be reflected as improved delivery performance and greater supply chain flexibility.

According to Bastas and Liyanage (2018), quality management integration seeks the involvement of company managers and operators in general within the organization. Conversely, supply chain management seeks external associations with suppliers and customers that result in a synergic environment of collaboration and cooperation among all the supply chain partners. The ultimate goal of both quality management integration and supply chain management is to achieve customer satisfaction. Thanks to the implementation of quality management practices, such as continuous improvement and leadership, it is possible to increase organizational performance (Duran-Fernandez and Santos 2014). Authors such as Terziovski and Hermel (2011) argue that supply chain performance can be improved through the quality management principles and the deployment of continuous improvement concepts along the system.

Advanced manufacturing technology (AMT) has proved to have significant benefits. They minimize costs and contribute to product quality, since they can streamline the implementation of design changes and improve product design itself. Additionally, AMT has a positive impact on delivery times: It allows companies to manufacture a wide array of customized products in short times and efficiently (Okure et al. 2006). In this sense, AMT reduces cycle times and manual jobs, such as part assembly (García Alcaraz et al. 2012). Similarly, it has been demonstrated that AMT positively influences the flow of materials and improves problem-solving (Koufteros et al. 2014). In other words, advanced technology, including information technologies, either increase or decrease output levels and thus flexibility (Heim and Peng 2010).

Costs are usually considered as a performance aspect. Inventory and transportation costs, among others, must be taken into account when assessing business profitability. Likewise, costs allow supply chain performance to be measured. In this sense, manufacturing practices, such as JIT, TQM, or AMT, among others can have an impact on corporate and supply chain benefits (Vinodh and Joy 2012). This premise has been tested in a variety of research environments. For instance, Khanchanapong et al. (2014) and Vinodh and Joy (2012) developed structural equation models to explore the impact of lean manufacturing practices and advanced manufacturing technology in operational performance of production systems. Following this discussion, the fifth research hypothesis for the integrative model can be proposed as follows:

H_5. In the manufacturing industry, *Manufacturing Practices* have a positive direct impact on supply chain *Performance*.

Risk factors can have effects on lean manufacturing processes, and consequently, on some aspects of supply chain performance. The literature reports a vast array of research works that address potential risk factors as well as their impact on supply chain performance. For instance, a study explores demand risks and their impact on inventory availability (Rotaru and Pournader 2018). Since supply chain risk is associated with variations in demand, supply, or production processes, it has an important effect on inventory costs and thus on supply chain financial performance. Risks from various sources originate from a lack of information and cause failures in the quality of products (Sreedevi and Saranga 2017). For instance, risks due to poor-quality suppliers have a serious impact on total product costs (Chavez and Seow 2012). On the other hand, quality failures and incorrect raw material deliveries cause production delays and consequently late product deliveries.

Risks are inherent in supply chain systems, which is why companies must rely on effective strategies to mitigate them and survive in harsh conditions without compromising quality and customer satisfaction (Chavez and Seow 2012). Previous studies highlight the positive effects of suppliers in final product quality and corporate performance (Al-Tit 2017) and support the claim that suppliers play a crucial role in the whole supply chain. Following this discussion, the last research hypothesis of the integrative model can be proposed as follows:

H_6. In the manufacturing industry, external and internal supply chain *Risks Factors* have a negative direct impact on *Supply Chain Performance*.

15.3.2 Latent Variable Validation Process of Integrative Model

This section validates the latent variables proposed for the integrative model. Seven latent variable coefficients were estimated as discussed in the methodology chapter. Since this is a second-order model, none of the latent variables here explored has been validated or tested in previous models. Table 15.9 reports the validation results as follows:

According to the values of R^2, adjusted R^2, and Q^2, the dependent latent variables have enough predictive validity from both parametric and nonparametric perspectives. Similarly, the composite reliability index and the Cronbach's alpha

Table 15.9 Latent variable coefficients: *Integrative Model*

Coefficients	Risks factors	Regional factors	Manufacturing practices	Supply chain performance
R-Squared (R^2)		0.314	0.305	0.549
Adjusted R^2		0.311	0.299	0.543
Composite reliability	0.870	0.848	0.900	0.886
Cronbach's alpha index (CAI)	0.701	0.784	0.852	0.844
Average variance extracted (AVE)	0.770	0.584	0.693	0.566
Full collinearity VIF	1.547	1.436	2.167	2.082
Q-Squared (Q^2)		0.307	0.307	0.547

demonstrate that all the latent variables have internal validity. On the other hand, AVE and VIF respectively confirm convergent validity reliability and the absence of collinearity problems. The latent variables can now be statistically associated to determine the model's efficiency.

15.3.3 Results of Integrative Model Evaluated

The model was tested according to the methodology chapter. The results of that test are illustrated in Fig. 15.6. As in previous models, each direct relationship or hypothesis is associated with a β value and a P value. The former is a measure of dependency, whereas the latter indicates the statistical significance of the effects. Relationships that are statistically significant have a P value lower than 0.05. Finally, the dependent latent variable in each relationship includes an R^2 value as a measure of explained variance.

According to the estimated parameters depicted in Fig. 15.6, the ten model fit and quality indices were estimated as follows:

- Average Path Coefficient (APC) = 0.332, $P < 0.001$
- Average R-Squared (ARS) = 0.378, $P < 0.001$
- Average Adjusted R-Squared (AARS) = 0.373, $P < 0.001$
- Average block VIF (AVIF) = 1.587, acceptable if ≤ 5, ideally ≤ 3.3
- Average Full collinearity VIF (AFVIF) = 1.808, acceptable if ≤ 5, ideally ≤ 3.3

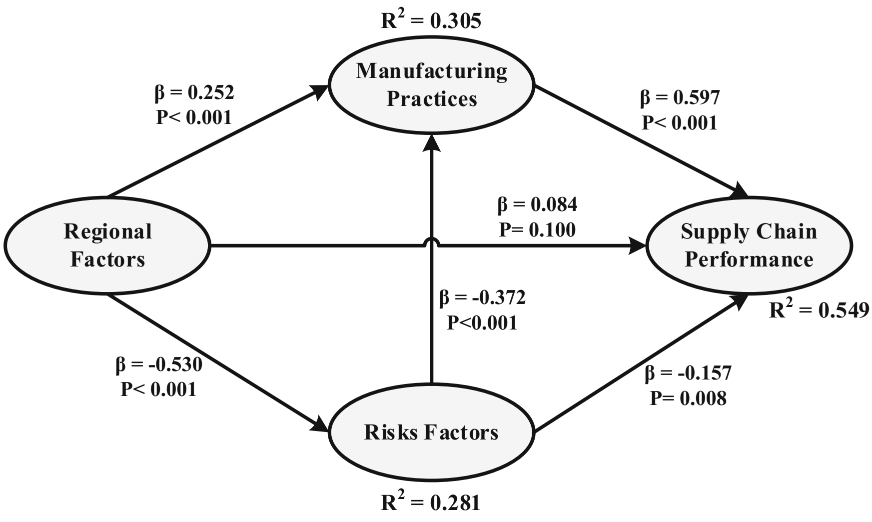

Fig. 15.6 Integrative model evaluated: *Regional Factors–Risks Factors–Manufacturing Practices–Supply Chain Performance*

- Tenenhaus GoF (GoF) = 0.488, small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36
- Simpson's Paradox Ratio (SPR) = 1.000, acceptable if ≥ 0.7, ideally =1
- *R*-Squared Contribution Ratio (RSCR) = 1.000, acceptable if ≥ 0.9, ideally =1
- Statistical Suppression Ratio (SSR) = 1.000, acceptable if $\geq$ 0.7
- Nonlinear Bivariate Causality Direction Ratio (NLBCDR) = 1.000, acceptable if ≥ 0.7

According to the Tenenhaus GoF, the model has a good fit. Notice that the value is even higher than the cutoff. Furthermore, APC indicates that, in average, all the estimated β parameters are statistically significant. As for ARS and AARS, their *P* values are lower than 0.05 and demonstrate that the model has enough predictive validity. Finally, AVIF and AFVIF indicate the absence of collinearity problems. According to the information model and results, it can be interpreted as follows.

15.3.4 Direct Effects

The direct effects or hypotheses tested and illustrated in Fig. 15.5 can be interpreted as follows:

H_1. There is enough statistical evidence to claim that *Regional Factors* have a positive direct effect on *Manufacturing Practices*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.252 standard deviations.

H_2. There is enough statistical evidence to claim that *Regional Factors* have a negative direct effect on the perception of supply chain *Risks*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by −0.530 standard deviations.

H_3. There is enough statistical evidence to claim that supply chain *Risks Factors* have a negative direct effect on *Manufacturing Practices*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by −0.372 standard deviations.

H_4. There is not enough statistical evidence to claim that *Regional Factors* have a positive direct effect on supply chain *Performance*. The *P* value related to this relationship is higher than 0.05.

H_5. There is enough statistical evidence to claim that *Manufacturing Practices* have a positive direct effect on *Supply Chain Performance*, since when the first latent variable increases by one standard deviation, the second latent variable increases by 0.597 standard deviations.

H_6. There is enough statistical evidence to claim that supply chain *Risks Factors* have a negative direct effect on *Supply Chain Performance*, since when the first latent variable increases by one standard deviation, the second latent variable decreases by −0.157 standard deviations.

15.3.5 Effect Sizes

Table 15.10 reports the effect sizes found in the model, since two or more independent latent variables explain a dependent latent variable. The R^2 values are decomposed into the effect sizes.

According to Fig. 15.6 and the information summarized in Table 15.10, it is possible to propose the following conclusions as regards the variability of the dependent latent variables:

- Supply chain *Risks Factors* explain to a large extent the variability of *Manufacturing Practices*. However, the role of such risks is not as important in supply chain *Performance*, since their explanatory power is low if compared to other latent variables that also affect performance benefits. However, this result is valid only in this research.
- *Manufacturing Practices* have the most important contribution to supply chain *Performance.* Such results imply that manufacturers must strive to minimize production processes risks and appropriately implement good lean manufacturing practices and philosophies in the production system.
- *Regional Factors* that result from poor management from governments are a source of supply chain *Risks.* Therefore, it is important that governments strive to provide the necessary transportation infrastructure, effective communication and logistics services, and less bureaucracy. Similarly, since a poorly qualified workforce is a source of risk, governments are responsible for providing and support education systems and programs that meet the performance needs and requirements of the manufacturing industry.
- Finally, *Regional Factors* are a source improvement in *Manufacturing Practices.* A skilled and experienced workforce improves the production system, makes companies more competitive, and improves decision making at the operational level. Such benefits are ultimately reflected as better products.

Table 15.10 Effect sizes in the integrative model

To	From			R^2
	Risks factors	Regional factors	Manufacturing practices	
Risks factors		0.281		0.281
Manufacturing practices	0.190	0.115		0.305
Supply chain performance	0.082	0.039	0.428	0.549

Table 15.11 Sum of indirect effects in the integrative model

To	From	
	Risks factors	Regional factors
Manufacturing practices		0.197 ($P < 0.001$) ES = 0.090
Supply chain performance	−0.222 ($P < 0.001$) ES = 0.115	0.352 ($P < 0.001$) ES = 0.163

15.3.6 Sum of Indirect Effects

Table 15.11 reports the effect sizes found in the indirect relationships between latent variables, which occur through mediator variables. According to such results, the following interpretations can be provided:

- *Regional Factors* play a crucial role in *Supply Chain Performance.* They ensure the availability and proximity of raw materials and workforce and facilitate legal procedures. However, their influence on supply chain efficiency depends on the adequate implementation of *Manufacturing Practices* and *Risk* mitigation strategies, which ensure the flow of materials along the production process. According to Table 15.11, the indirect effect from *Regional Factors* to *Performance* is the highest; however, the direct relationship was statistically not significant. Such results indicate that *Regional Factors* must be transformed into a competitive advantage during the implementation of *Manufacturing Practices* in the production system.
- Supply chain *Risks Factors* that are poorly handled have a negative impact on *Manufacturing Practices* and thus on *Supply Chain Performance*. The indirect effect between the first and the third latent variables through the second latent variable is negative and shows $\beta = -0.222$. Such results indicate that *Risks* must be mitigated before they affect the production process and the performance indices.
- Finally, *Regional Factors* have indirect effects on *Supply Chain Performance* through *Manufacturing Practices.* Such results imply that if companies appropriately take advantage of infrastructure resources and governmental support, they have two strong competitive advantages. The unnecessary bureaucracy in local governments and a lack of appropriate infrastructure are sources of risk in the supply chain and can affect economic benefits.

15.3.7 Total Effects

Table 15.12 reports the total effects found in the relationships of the integrative model. According to such results, it is possible to conclude the following:

Table 15.12 Total effects in the integrative model

To	From		
	Risks factors	Regional factors	Manufacturing practices
Risks factors		−0.530 ($P < 0.001$) ES = 0.281	
Manufacturing practices	−0.372 ($P < 0.001$) ES = 0.190	0.449 ($P < 0.001$) ES = 0.205	
Supply chain performance	−0.379 ($P < 0.001$) ES = 0.197	0.449 ($P < 0.001$) ES = 0.202	0.597 ($P < 0.001$) ES = 0.428

- Supply chain *Risks Factors* have a negative impact on *Manufacturing Practices* and *Supply Chain Performance* ($\beta = -0.372$ and $\beta = -0.379$, respectively). Manufacturing companies that do not properly and continuously forecast demand might not be able to properly implement *Manufacturing Practices* in the production system, where changes in parts and models are constantly changed. Consequently, little or poor mitigation will not only affect the production process. It will cause a bullwhip effect, thereby compromising potential benefits and *Supply Chain Performance*.
- The relationship between *Manufacturing Practices* and *Supply Chain Performance* has the largest total effects. These effects occur thanks to the direct relationship between the latent variables and imply that *Manufacturing Practices* in the surveyed companies are under control and contribute to gaining benefits.
- The relationship between *Regional Factors* and supply chain *Risks Factors* has the second largest total effects ($\beta = -0.530$). This implies that *Regional Factors* are usually seen as an area of opportunity, since they can be important sources of *Risks*.
- *Regional Factors* have important effects on *Manufacturing Practices* and *Supply Chain Performance*. Therefore, companies must take full advantage of regional infrastructure, information technologies, and services to improve the system and enhance the efficacy and effectiveness of the supply chain.

15.3.8 Conclusions and Industrial Implications for Integrative Model

The integrative model explores the relationships between three major impact factors—*Regional Factors*, *Manufacturing Practices*, and *Risks Factors*—and *Supply Chain Performance*. According to the analyses performed in the previous section, it is possible to propose the following conclusions and industrial implications for the integrative model:

- The levels of *Risks Factors* perceived by the manufacturing companies surveyed in this book do have an impact on *Supply Chain Performance* at any stage. In other words, the higher the level of perceived risks, the fewer benefits are obtained. In this sense, we found that the direct effect between these two variables is negative. Moreover, supply chain *Risks Factors* directly affect the implementation of *Manufacturing Practices*. The effect of this relationship is also negative and implies that even though manufacturing companies rely on effective *Manufacturing Practices*, potential sources of *Risks Factors* can compromise the effectiveness of these practices. It is thus important to develop and implement risk mitigation strategies in the supply chain to both increase economic benefits and customer service.
- This research found a good implementation and use of information and communication technologies (ICTs) among the surveyed companies. The main advantages of such technologies are that they improve communication among partners and with customers and improve supply chain integration. The use of ICTs is thus a potential risk mitigation strategy when these technologies are focused on improving or enhancing subjective aspects, such as commitment, collaboration, trust, and integration.
- Regional Factors in the surveyed region are acceptable; however, their effect on supply chain *Risks Factors* is negative. On the one hand, this relationship implies a lack of governmental support at all levels (i.e., local, regional, national) that reflects on the existing public policies, legal procedures, and the level of transparency. Consequently, the levels of risks in demand, supply, or the production process will be higher if companies lack this support. On the other hand, the level of *Risks Factors* perceived in the supply chain is also the result of existent public services, infrastructure, service costs, quality of life, and workforce in the region. A skilled and experience workforce improves and streamlines the decision-making process and enhances corporate competitiveness.
- *Regional Factors* play an important role in the implementation of *Manufacturing Practices.* In other words, internal production processes are affected by external and environmental aspects, since companies rely on worker experience and skills, transportation infrastructure, and ICTs, among others. Furthermore, costs associated with human resources employment, land acquisition, and services must be accessible for companies to become and remain profitable. In the industrial sector, this claim implies that manufacturers cannot operate independently from their environment. In fact, supply chain benefits and corporate competitiveness depend on external aspects associated with the environment where companies operate. This claim is validated among manufacturing industries, from where it can be concluded that improving supply chain performance depends on the following key regional factors: infrastructure, governmental support, costs, services, workforce, market proximity, and quality

of life. This claim supports the importance of human resources in the process of reaching the desired performance and thus benefits.

- *Regional Factors* are an area of opportunity to improve the perception of supply chain *Risks Factors* in the manufacturing industry. However, some of these factors cannot be controlled by the companies and rather respond to a governmental administration.
- *Manufacturing Practices* play a key role in supply chain performance. Their contribution to *Supply Chain Performance* is the highest for this integrative model. Such results demonstrate the importance of well-controlled internal processes that ensure quality products, punctual delivery times, and competitive prices.
- This research found that the influence of supply chain *Risks* in the relationship between *Regional Factors* and *Supply Chain Performance* is not statistically significant. Hence, as further research, we suggest studying the direct relationship between regional elements and supply chain performance without the presence of the mediator variable (i.e., *Risks Factors*).

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