Lecture Notes in Management and Industrial Engineering

Josefa Mula · Rafael Barbastefano
Manuel Díaz-Madroñero · Raúl Poler
Editors

New Global Perspectives on Industrial Engineering and Management

International Joint Conference
ICIEOM-ADINGOR-IISE-AIM-ASEM

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Lecture Notes in Management and Industrial Engineering

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Editors
Josefa Mula
Research Centre on Production Management and Engineering (CIGIP)
Escuela Politécnica Superior de Alcoy
Universitat Politècnica de València
Alcoy, Alicante
Spain

Manuel Díaz-Madroñero
Research Centre on Production Management and Engineering (CIGIP)
Escuela Politécnica Superior de Alcoy
Universitat Politècnica de València
Alcoy, Alicante
Spain

Rafael Barbastefano
Brazilian Association of Production Engineering—ABEPRO
Rio de Janeiro, Brazil

Raúl Poler
Research Centre on Production Management and Engineering (CIGIP)
Escuela Politécnica Superior de Alcoy
Universitat Politècnica de València
Alcoy, Alicante
Spain

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Preface

It is an honor to present a selection of papers that were accepted at the International Joint Conference—ICIEOM-ADINGOR-IISE-AIM-ASEM (IJC 2017).

This Joint Conference is a result of an agreement among Asociación para el desarrollo de la Ingeniería de Organización (ADINGOR), Associaçâo Brasileira de Engenharia de Produçâo (ABEPRO), Institute of Industrial and Systems Engineers (IISE), European Academy for Industrial Management (AIM), and American Society for Engineering Management (ASEM). The conference was organized by the Research Center on Production Management and Engineering (CIGIP) at Universitat Politècnica de València, Spain.

The International Joint Conference (IJC2017)'s motto was "New Global Perspectives on Industrial Engineering and Management." The mission of the conference was to promote links between researchers and practitioners from different branches, to enhance an interdisciplinary perspective of industrial engineering and management.

The contributions of this book have been organized in seven parts:

- Strategy and Entrepreneurship
- OR, Modelling, and Simulation
- Logistics, Production, and Information Systems
- Quality and Product Management
- Knowledge and Project Management
- Service Systems
- Education

Strategy and entrepreneurship contributions are, mainly, oriented to capacity planning, product development, innovation, energy sources, and operation resources. Operation research, modeling, and simulation proposals are focused on the perception of users, quality of life, expenditures on education, drayage problems, demand variability, city resilience, investment valuation, security policies and recycling, among others. Logistics, production, and information systems papers address reverse logistics, risk identification, value stream mapping, maintenance management, health chains, additive manufacturing, timetable planning, disaster management, Arduino and RFID, supply chain uncertainty and ecodesign. Quality and product management consider aspects related to competitive priorities, design thinking, total productive maintenance, water consumption, and lean manufacturing. Knowledge and project management contemplate topics regarding hidden costs in offshoring and project portfolio selection, among others. Service systems are focused on health delivery scheduling and culture of hospital quality. Finally, education contributions analyze the technology transfer outputs versus publications and evaluation rubrics.

Alcoy, Alicante, Spain — Josefa Mula
Rio de Janeiro, Brazil — Rafael Barbastefano
Alcoy, Alicante, Spain — Manuel Díaz-Madroñero
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Part I
Strategy and Enterprepreneurship

Long Term Capacity Planning: The Comparison Between the Net Present Value, Return on Investment and Unitary Cost for Scale Analysis

A. Santa Catarina

Abstract This paper is motivated by discussing the long-term capacity decision making. This decision is especially relevant to capital intensive production processes that require long-term planning. Among the many questions related to this subject, this paper aims to apply three financial parameters to compare scale alternatives. They are the Unitary Cost (UC), the Return on Investment (ROI) and the Net Present Value (NPV) and were calculated for a hypothetical process composed by two main resources. As results, the paper shows that the first two methods despite being trivial to apply don't have reliable results while the NPV proves itself as good parameters to compare the alternatives. It is also presented a sample of the use of the NPV as a parameter to analyse the scale as a meter to define the competitive strategy.

Keywords Long-term capacity · Long-term planning · Net Present Value
Scale

1 Introduction

In the development of new businesses, one of the great decisions to be taken is the definition of long-term productive capacity. This decision influences the capital budget of the venture and also the risk of sizing a production system incompatible with the market demand. This decision-making process must take into account several relevant aspects, among which it is possible to mention: the scalability of the production process, competitive strategies, economic and financial viability.

The development of models for long-term analysis and capacity planning involves several the dimensions where the financial result can be used as a quantitative parameter to compare the alternatives. Since the system to be analyzed is

A. Santa Catarina (✉)
Dpto. de Engenharia de Produção E Sistemas, Centro Tecnológico, Universidade Federal de Santa Catarina, Campus Universitário Trindade, Florianópolis, Santa Catarina, Brasil
e-mail: artur.catarina@ufsc.br

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financially modeled, it is possible to use this model to compare scenarios that allow on exploring the impact of the possible competitive strategies.

There are quite a few details to perform a good scale analysis but one of the main issues is to choose among different financial parameters in order to compare the scale alternatives. Traditional operations management literature uses the unitary cost with this objective, comparing the unitary cost of each scale option and choosing for the smallest unitary cost option. This parameter has some limitations like not including the initial investment and different price strategies. These problems are solved by the use of the Return on Investment index (ROI), but it doesn't solves other problems that happens to both of the cited parameters like ignoring the time value of money (interest) and the long-term period of analysis that is a characteristic of this kind of investment. These issues are solved by using the Net Present Value (NPV) as a parameter, but it is not usually applied.

Considering the presented context this work aims to compare these three different parameters in a scale analysis of a hypothetical case of process composed by two main resources. The paper also aims to use the model developed to perform a sample of the analysis of the issue competitive strategy versus scale. The subject is wide so there is no intention to exhaustively discuss it.

2 Long-Term Capacity Analysis

The long-term capacity analysis is the activity to provide information to support taking decisions about the scale or the size of the production systems. This kind of analysis is relevant for capital intensive systems that are designed to operate throughout many years which make it an almost irreversible investment. Long-term planning, in a broader sense has issues related to the product life-cycle, the types and numbers of equipment's necessary to produce a given amount of products, the types of processes and the work force required (Duenyas et al. 1994). Long-term capacity analysis is different from short or medium term capacity analysis because in this last two major physical changes are not expected (Slack et al. 2002).

The possibility of changing a production system's scale is called scalability, which is a property that allows it to change its capacity to adapt to the demand (Putnick et al. 2013). ElMaraghay (2005) classifies the scalability in two kinds, the logical/soft and the physical/hard scalability. Fricke and Shulz (2005) present two principles by which a production system may be physically modified, the first is by varying the number of identical productive elements (e.g. with more or less machines) and the second is by varying the capacity of the element (e.g. acquiring machines with more or less productive capacity). Putnick et al. (2013) argue that the two principles can also be combined.

The production scale depends on some elements, the main are the productive capacity (units/time), the quantity of resources (number of machines and/or operating stations) and the way they are organized (layout or architecture of the system). The architecture of the system, that is, how it is organized, also has great influence on its productive capacity. Long-term capacity is also influenced by the systems flexibility because once the system is able to be adapted with the changes in the demand; the risk of the scale decision can be mitigated. Flexibility is good, but it has a price, so the option for the level of flexibility must take in account its cost/benefit (Fricke and Schulz 2005).

The options available to build productions systems with different sizes depend on the technical specificities of each process and to acknowledge and analyze these options it worth following some steps as proposed here.

1. Analysis of the scalability of the productive process.
2. Selection of the alternatives of production scale.
3. Choosing among the scale analysis methods.
4. Tabulation of data and analysis of alternatives.
5. Size choice.

The first stage is the time to study the productive process to know the main productive resources, the alternative productive capacities for each resource, the main ways of organizing them. The second stage lists the size alternatives, with more or less productive capacity. In the third step, the methods for choosing the size should be chosen and in the fourth step the data of each of the alternatives are organized and tabulated allowing the application of the chosen method. Finally, in the possession of the available information, each of the alternatives must be analyzed, presenting its advantages and disadvantages and the strategic impact. The next section disserts about scale analysis methods.

3 Scale Analysis Methods

The methods of analysis of size compared in this work have as main characteristic to quantify the alternatives in monetary terms, in the form of some parameter that allows the comparison between the alternatives. The most traditional is the unit cost method, followed by the profitability method, and finally, there is also the return analysis method. So this section starts by the unitary cost as it follows.

3.1 Unitary Cost Method

This method evaluates the alternatives of productive scale by the estimation of the unitary cost, being considered better, the alternative with the lowest cost. Casarotto Filho (2009) cites this as being the method used in traditional scale definition models. Examples of this approach can be found in Slack et al. (2002) where the unitary cost is calculated by dividing the sum of fixed and variable costs by process outputs. The outputs of the process are given in the unit chosen to measure the productive capacity.

In this method, the unitary cost ends up being an average unit cost as a function of the product-mix of the production system under analysis. For each production system configuration, with a given nominal capacity, there will be a minimum average unitary cost, found for the economic use of the nominal productive capacity.

It is expected that the minimum unitary cost will vary for different levels of nominal capacities according to the economies and diseconomies of scale as put by Slack et al. (2002). Economies of scale would be due to the reduction of fixed cost and capital per unit for higher productive capacities and diseconomies would come from increased costs due to higher logistical costs and complexity, from certain levels of productive capacity. The unitary cost is usually illustrated on the "U" shape graph, where the "right" size is the scale that minimize the unitary cost.

This method is criticized by not considering the interest cost and the capital structure (Casarotto Filho 2009). It is also limited by not allowing considering different price strategies.

3.2 Return on Investment Method

The ROI is also used as a parameter to compare the size alternatives. The index is calculated dividing the annual shareholder cash flow (Sa) by the initial investment (Ia) as proposed by Casarotto Filho (2009). According to the reference, the next scale is considered better if the expected ROI bigger as it is possible to see in the inequality that follows.

Return on Investment equation for scale analysis.

$$\frac{\mathrm{Sa}_{(e+1)}}{\mathrm{Ia}_{(e+1)}} \geq \frac{\mathrm{Sa}_{(e)}}{\mathrm{Ia}_{(e)}} \qquad (1)$$

As weaknesses of this method, two points can be cited, the first is to ignore the time value of money, i.e. the cost of capital, when comparing monetary values at different times, since annual balances usually occur throughout many years and the investment usually takes place in the initial periods of the project. The second point is not to account for the accumulated effect of the balances during the enterprise life cycle.

Both fragilities can be overcome by the net present value that is discussed at the next section.

3.3 The Net Present Value Method

This method calculates the present value of the expected cash flow for the analysis horizon and subtracts it from the initial investment the value if the result o it is bigger than zero, it means de the investment is economically viable. The result found represents the venture's expected value in the present moment, so the higher the NPV, the greater the value added to its shareholders (Casarotto Filho and Kopittke 2010). When analyzing the productive scale for an enterprise, one must calculate the NPV for each of the productive capacity alternatives and compare the values, and the method indicates that the productive scale with the highest NPV and the one with the highest expectation of return on investment. The present value is calculated using an interest rate that represents de cost of capital.

The NPV method is considered appropriate to do these analyzes, among other reasons to allow the comparison of investments with different values. The Internal Rate of Return (IRR) method is not considered for size analyzes precisely because it does not allow the direct comparison of investments of different values. The limitation of the NPV method are usually related to the uncertainties on the definition of the cost of capital and the other variables that are inputs for this method.

4 Analysis of Results

This paper explores a hypothetical case of a production system that had been created to fit to the objectives of this paper. It is a process composed by two main resources (r1 and r2) with the characteristics presented in the Table 1.

These resources can be combined, using different quantities of each to achieve alternative scales of production capacity. Each resource has its own variable and fixed costs in way that every alternative of size operates in its own level of fixed costs according to the number of resources combined. For the analysis it was arbitrated that the cost of capital is around 12.68% per year (1% p.m.), 10 years of life for the resources that would end up this time with the salvage value of 10%. It was also considered a first scenario with a sales price of $70 per unit.

In Table 2, five scale alternatives are proposed with its respective capacity, scale gain and investment.

S_1 is the result of the combination of one of both resources, S_2 has two r1 and one r2, S_3 has three r1 and two r2, S_4 has four r1 and two r2, and S_5 has five r1 and

Table 1 Main resources characteristics

	r1	r2
Capacity (unit/month)	70	160
Investment ($)	10.000	13.000
Variable cost ($/unit)	10	15
Fixed cost ($/month)	1.000	2.000

Table 2 Capacity alternatives from 1 till 5 and it's respective process capacity, scale gain and investment

	S_1	S_2	S_3	S_4	S_5
Process capacity (unit/month)	70	140	210	280	320
Relative scale gain (%)		100	50	33	14
Accumulated scale gain (%)		100	200	300	357
Investment ($)	23.000	33.000	56.000	66.000	76.000

Table 3 Unitary Cost (UC), Return on Investment (ROI) and Net Present Value (NPV) for each capacity alternative

	S_1	S_2	S_3	S_4	S_5
UC ($/unit)	67.86	53.57	58.33	53.57	53.13
ROI (%)	7.83	83.64	52.50	83.64	85.26
NPV ($)	−11.84803	128.31108	116.46305	256.62217	302.68558

Table 4 Demand balance point to each scale alternative

	S_1	S_2	S_3	S_4	S_5
Capacity use (%)	–	71	82	71	70
Capacity use (units)	–	99	172	198	223

three r2. The next table presents the results for the three methods calculated for 100% of their capacities.

By analyzing the UC and the ROI parameters, the alternatives 2 and 4 look better because they present the lowest unitary costs and the higher return on investment. With the NPV method the 5th alternative is the best because it can add more value to the investor. S_1 would be economically unviable presenting a negative NPV. This last information wasn´t delivered by the other two methods because they simply ignore the cost of capital and are not able to accumulate it throughout the years.

It is still possible to make further analysis with the NPV method. The data presented at the Table 3 were calculated considering a demand that could cover 100% of its installed capacity. As there is no guaranty that the company would be able to sell the entire production, it is important to analyze what happens with different levels demand. The Table 4 presents the results for the demand balance point for each scale alternative indicating the level of use that allows then to became feasible, according to the rule NPV >0.

These information is very important because the decision making must take in account the demand´s forecast. S_1 is economically unfeasible even with 100% of capacity. S_2, the lowest scale, only gets viable with 99 monthly units demand. So the first conclusion is that, it only worth operating this business from this level of demand at this scale. To go on with this analysis it is important to find the demand balance point that turns one alternative better than the other. Comparing S_2 and S_3 NPVs, using the data at Table 3, it is possible to see that the S_2 dominates S_3 in

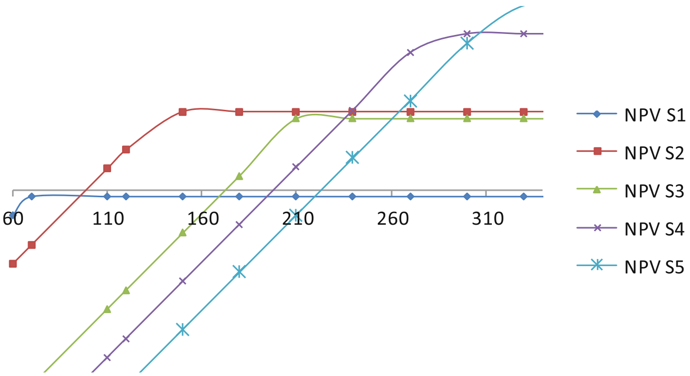

Fig. 1 Net Present Value (NPV) × Demand for each scale option $70 per unit

every range of demand. When comparing S_2 and S_4 NPV, it is only worth operating S_4 with demand of 239 monthly units. Making the same analysis between S_4 and S_5, the last one only gets better with a demand of 305 units per month, representing 95% of capacity. These data is plotted in the Fig. 1 where the NPV of each scale variates with the demand in units per month.

The economic viability of each scale happens when it´s line acroases the demand axe and the balance point among scales is given by the intersection between the lines.

Taking in account the presented information, the scale choice would depend on the demand's forecast for the aimed market segment where the decision would be deciding among the S_2 and S_4 according to the market strength. At the first scenario, operating at S_1 scale isn't worth but, for this issue it comes in play one more dimension of analysis which is the price. If there was the possibility to operate in a higher value market segment than it is a second scenario, where the sales price could be around $90 per unit, than the results would change for S_1 and S_3, as showed at Fig. 2.

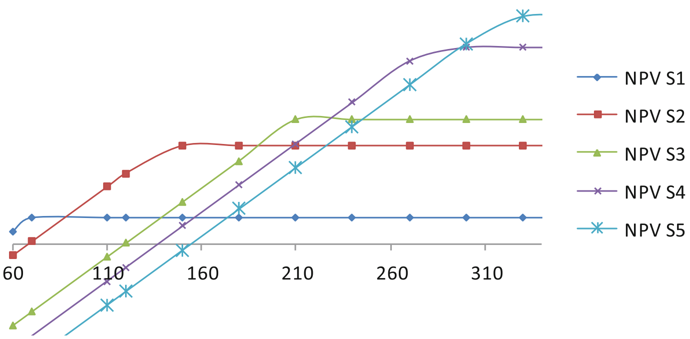

Fig. 2 Net Present Value (NPV) × Demand for each scale option at price $90 per unit

In this situation the company would change its competitive strategy by adding value to the costumer, allowing the option for a smallest scale, moving from the cost leadership to the differentiation strategy.

5 Considerations

Most of the decision taken when planning production systems must consider its and risk return. So, in the long-term capacity decision it is important to choose a parameter that can compare the expected return of the scale options. To feet with this objective the Unitary Cost, the ROI and the NPV were compared. The unitary cost has the advantage of been traditionally explored in the operations management literature using a simple math. The ROI also has a trivial math and work as a first measure about the return expected for each alternative. These two methods ignore the cost of capital and also don't take in account the entire investments life-cycle not been adequate to analyze capital intensive production processes. The NPV, despite requiring a better level of knowledge to be well applied, allows the comparison of the scale alternatives in terms of the value added to the sponsors. This paper demonstrated that the NPV is applicable to analyze the issue competitive strategies *versus* scale by quantizing distinct scale scenarios.

The material presented in this paper is only a sample of what is possible to make in terms of modeling this kind of analysis once in real cases other variables must be taken in account. For future works it is suggested the use of the system dynamics theory and tools to emulate long-term multi-variable scenarios. The use of simulation tools such as Arena are also an interesting approach on studding the scalability issue.

References

Casarotto Filho, N., & Kopittke, B. H. (2010). *Análise de Investimentos: matemática financeira, engenharia econômica, tomada de decisão, estratégia empresarial* (11ª ed.). São Paulo, Brasil: Atlas.

Casarotto Filho, N. (2009). *Elaboração de projetos empresariais: Análise, Estratégia*. Atlas, São Paulo, Brasil: Estudo de viabilidade e Plano de negócio.

Deif, A. M., & ElMaraghy, H. A. (2007). Assessing capacity scalability policies in RMS using system dynamics. *International Journal of Flexible Manufacturing Systems, 19,* 128–150.

Duenyas, L. F., John, W. S., & Lee, W. (1994). Planning and scheduling in Japanese semiconductor manufacturing. *Journal of Manufacturing Systems 13*(5), 323–332. https://doi.org/10.1016/0278-6125(94)P2582-Y.

ElMaraghy, H. A. (2005). Flexible and reconfigurable manufacturing systems paradigms. *International Journal of Flexible Manufacturing Systems, 17,* 261. https://doi.org/10.1007/s10696-006-9028-7.

Fricke, E., & Schulz, A.-P. (2005). Design for changeability (DfC): Principles to enable changes in systems throughout their entire lifecycle. *Systems Engineering, 8*(4), 342–359.

Putnick, G., Sluga, A., ElMaraghy, H., Teti, R., Koren, Y., Tolio, T., & Hon, B. (2013). Scalability in manufacturing systems design and operation: State-of-the-art and future developments roadmap. *CIRP Annals—Manufacturing Technology*, 751–774.

Slack, N., Chambers, S., & Johnston, R. (2002). Administração da Produção. 2a. Edição. Editora Atlas, São Paulo, Brasil.

Investigating the Impact of Process Innovation Over Profitability and Productivity: A Food Sector Application

B. Felekoglu and S. Ozmehmet Tasan

Abstract One of the main approaches that production companies apply in order to get the competitive advantage is process innovation. Under favor of process innovation applications, the facts like cost improvements, increase in product quality and customer satisfaction and increase in employee satisfaction and motivation have direct or indirect impacts on business profit. In consideration of these concepts, in this study a process innovation application in production sub-processes of packaging and filling of a company that is operating in food sector is explained in detail. The facts like costs, quality, and customer satisfaction are compared between former system and the new system after that process innovation application.

Keywords Innovation · Process innovation productivity

1 Introduction

Companies try to survive with the differences they create compared to their competitors in today's environment where the dimensions of the competition are redefined every day. Companies have to develop innovative approaches to make a difference since the costs they have to face according to their processes are close to each other, especially in production companies.

One of the main approaches that production companies apply in order to get the competitive advantage is process innovation. Process innovation is the implementation/adoption of new or significantly improved production or delivery methods which may involve changes in equipment, human resources, working methods or a combination of these (OECD 2005, p. 9). Under favor of process innovation applications, the facts like cost improvements, increase in product

B. Felekoglu · S. Ozmehmet Tasan (✉)
Department of Industrial Engineering, Dokuz Eylul University, Izmir, Turkey
e-mail: seren.ozmehmet@deu.edu.tr

B. Felekoglu
e-mail: burcu.felekoglu@deu.edu.tr

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quality and customer satisfaction and increase in employee satisfaction and motivation have direct or indirect impacts on business profit.

Although process innovation is important for competitive advantage, we still have little knowledge about the practices and implementation of new processes.

2 Objectives

In this study a process innovation application in production sub-processes of packaging and filling of a company that is operating in food sector is explained in detail using Process Innovation Lifecycle Framework developed by Milewski et al. (2015). The facts like costs, quality, customer satisfaction are compared between former system and the new system after that process innovation application.

3 Process Innovation

In OSLO Manual, process innovation is defined as the implementation/adoption of new or significantly improved production or delivery methods which may involve changes in equipment, human resources, working methods or a combination of these (OECD 2005, p. 9). Process innovation can be done to reduce unit production or delivery costs and/or improve quality. It can also be a new or significantly improved methods of service creation and provision or support activities. Process innovation can provide many strategic advantages such as lower transaction and production costs and strategic benefits from changes in buyer seller relationships, strategic benefits from close relationships with customers and suppliers and more competitive better quality products (Reguia 2014). Other utility-related advantages of process innovation include direct benefits from electronic transformation of information and reduced document costs, indirect benefits derived from in-house productivity, increase in employee satisfaction and motivation, better working conditions for the operators (Koellinger 2008). The difficulties of process innovation are mostly due to cost-based factors. These costs are often the costs incurred during the adaptation of process innovations (Boutellier et al. 2013).

Although process innovation is important for competitive advantage, we still have little knowledge about the practices and implementation of new processes. In process development changes in the processes as well as associated jobs, procedures, and work activities with the use of new technologies should be considered (Slack et al. 2013). Technological process innovation (TPI) should be done in a systematic way to better manage the process. Milewski et al. (2015) explain TPI from a lifecycle perspective and define four TPI components (See Fig. 1).

Process innovation lifecycle consists of four phases. Ideation involves generating new process alternatives. Adoption is the phase where activities for facilitating and making investment decisions take place. Preparation phase involves developing

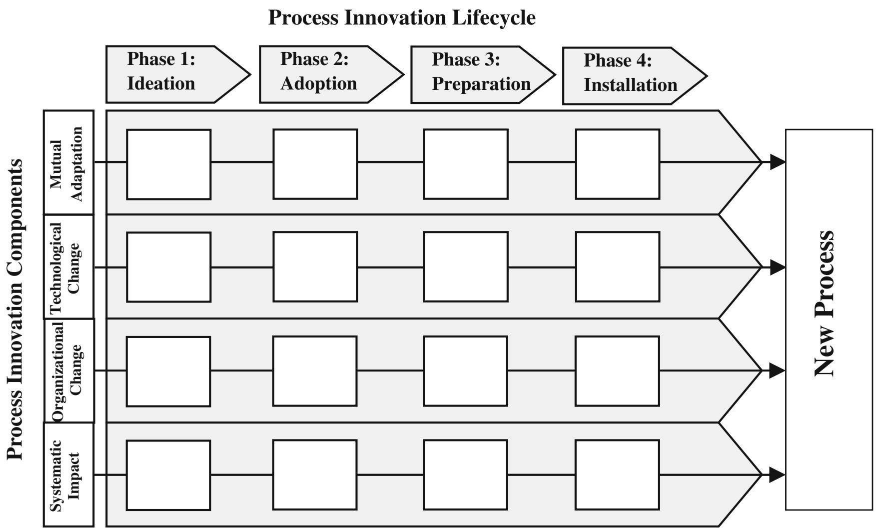

Fig. 1 TPI from a lifecycle perspective with specific attention to four TPI components (adopted from Milewski et al. 2015, p. 1316)

technology and planning for organizational change. In the installation phase, implementation of the new process including technology set-up and introduction of organizational change occurs.

In Fig. 1, we see four process innovation components. First component is mutual adaptation and it involves redesigning new technology and existing organization in order to harmonize them. Technological change implies changes in activities, outputs, and problems due to the relative advantage, complexity, compatibility, and communicability of the new technology. Organizational change covers changes occurring in work organization such as organizational, administrative and managerial systems or current processes and competencies due to the introduction of technological innovation. Systemic impact refers to the integration level of innovation with its broader system.

4 Methods

In depth case study methodology is used to fulfill the aim of this study. For the purpose of this study, Process Innovation Lifecycle Framework developed by Milewski et al. (2015) is used. This framework involves four process innovation components (i.e. mutual adaptation; technological change; organizational change; and systemic impact) and four stages of the process innovation life cycle (i.e. ideation; adaptation; preparation; and installation) as explained in the previous section.

The case company is operating in the food sector and established with an international partnership. For the purpose of confidentiality, identifying information has been removed or renamed from the case company profile. The company has an annual import volume of approximately 1600 tons of dry fruit and a turnover target of approximately 25 million dollars annually. The product range includes dried figs, dried apricots, dried mulberries, dried plums, dried cherries, dried mangoes and raisins. The production facility of the company is located in Izmir, Turkey where 40 white collar and 300 blue collar employees are working.

In this company, the product group which has the highest production period in terms of the total working hours spent is the dried fig group. Therefore, the product group which constitutes the highest total labor cost is also the dried fig group. The company decided that the dried fig packaging processes are insufficient to reach the level of profitability and quality that the enterprise desires and decided to implement a process innovation for this part.

5 Process Innovation Study

First of all, the existing packaging system in the dried fig packaging section was analyzed as the initial packaging process. Initial packaging process is shown in Table 1.

As it can be seen from this process flow, existing packaging process requires high-level human power. This causes serious disadvantages in terms of operation, serious production costs, quality problems and especially hygiene based production problems. Additionally, human-intensive processes unable the company to achieve the expected high levels of production capacity. With this packaging process, 20 staff works 9 h a day and provide a production capacity of 10,584 packages. This capacity means that a container full of products can be prepared in 7.9 days which corresponds to 1422 man-hours of work. With this working capacity, an average of 4 containers per month of product can be made ready for shipment.

For improving this packaging process, the company decided to do a process innovation following a systematic method using Process Innovation Lifecycle Framework (see Table 2).

Table 1 Initial packaging process

Work element	# of workers
Writing of expiration dates and party numbers on packages	2
Opening the mouths of the packages for filling	3
Moving of opened packages to the filling tables	1
Filling of packages on the filling tables	4
Weighing of filled packages	4
Fine weight control of filled and weighed packages	1
Zipper closure of controlled packages	1
Heat sealing of packages	1
Controlling, adjusting and boxing the packages	1
Placing and stacking of the boxes on the pallets	2

Table 2 Technological process innovation lifecycle framework

	Ideation	Adoption	Preparation	Installation
Mutual adaptation	**Enabling process:** Investigation of new technology alternatives for packaging system Evaluation of technological change suitability of personnel qualifications **Core process:** Deciding to replace the existing system with a new technological alternative	**Enabling process:** Determination of the new line to be used and the personnel qualifications required by this line **Core process:** Evaluation of basic and sub-processes of packaging system	**Enabling process:** Determining who will be assigned to the new line among employees **Core process:** Employee training for new line use	**Enabling process:** Getting feedback from employees about the new packaging line **Core process:** Changing the negative thoughts of employees to change the system
Technological change	**Enabling process:** Evaluating the advantages of the new system to be installed, such as cost, efficiency, speed and effectiveness **Core process:** Determining the features of the new technology to be acquired for business needs	**Enabling process:** Investigate alternative vendors that can provide new packing and filling lines **Core process:** Examination of elements such as drafting, computer simulation for evaluating the technological characteristics of the new system to be acquired	**Enabling process:** Providing motivation for staff to work on new packing and filling lines **Core process:** Determination of the appropriate location within the plant for installation of the line	**Enabling process:** Performing necessary personnel changes after performance evaluation **Core process:** Assessing the performance of personnel working on the new line

(continued)

Table 2 (continued)

	Ideation	Adoption	Preparation	Installation
Organizational change	**Enabling process:** Evaluating the processes in the old system and the efficiency of the personnel working in these processes	**Enabling process:** Evaluation of changes in packaging and filling system as a result of new line to be installed **Core process:** Informing the operator about the changes to be made by suppliers, customers, managers and employees	**Enabling process:** Meetings with employees of the new system **Core process:** Practices to increase the motivation of the employees towards the new system	**Enabling process:** Determination of personnel-induced defects in the new system **Core process:** Re-train employees as needed
System impact	**Enabling process:** Evaluation of the new line costs and the return of investment **Core process:** Evaluation of cost alternatives for new line	**Enabling process:** Considering systemic impact in decision making relating to other processes **Core process:** System integration work	**Enabling process:** Planning the basic processes for integration **Core process:** Evaluation of the basic processes for integration	**Enabling process:** Evaluating the potentials of the customer requirements in terms of the old system and the new system to be installed **Core process:** Reassessing sales targets in the light of the positive impact of the new system on productivity and the increase in operating capacity utilization

Table 3 New packaging process

Work element	# of workers
Feeding the dried figs to the vol-pack machine	1
Feeding packages (100 per) to the vol-pack machine	1
Boxing of packages	3
Use and control of the vol-pack machine	1

Table 4 Comparison of old and new fig packaging systems

	Number of employees	Daily number of packages available for sale	Preparation time for 1 container product (days)	Number of containers to be prepared monthly
Old packaging line	20	10,584	7.9	4
New packaging line	6	48,600	1.7	18
Change %	70% decrease	360% increase	78% decrease	350% increase

As a result of this technological process innovation the new packaging process is established. New packaging process is shown in Table 3.

With the new packaging system applied, daily production capacity became 48,600 packages prepared by 6 staff working 9 h a day. This capacity means that a container full of products can now be prepared in 1.7 days. In Table 4, the old and the new system are compared.

6 Results

Findings indicate that after the process innovation application in production sub-processes of packaging and filling of the company, the number of packages ready for sale is increased 4.6 times, while the number of personnel used is reduced about one third when performing this. Moreover, there is a significant increase in the level of capacity utilization of the business. In the old system, an average of 4 containers can be made ready for one month while this number has increased to about 18 containers per month with the new system. It is seen that serious improvements are made in the total production hours of the business. This means that the implementation of the process innovation not only has reduced the labor costs but also allowed the company to better meet the existing customer demands as well as new customer demands due to better capacity utilization. The ability to meet existing and new customer demands has also led to an increase in customer satisfaction. Additionally, with the new system, the rate of quality complaints is reduced to 1% from 5% which is also an indicator of better quality products and customer satisfaction.

7 Conclusion

Process innovation has many strategic advantages in terms of businesses. It incorporates holistic perspectives that enable businesses to achieve the targeted results in terms of cost, efficiency, quality etc. However, it is necessary to follow a systematic process from ideation to installation considering key components—mutual adaptation, technological change, organizational change, and systemic impact, in order to successfully implement any process innovation.

References

Boutellier, R., Gassmann, O., & Von Zedtwitz, M. (2013). *Managing global innovation: Uncovering the secrets of future competitiveness*. Berlin: Springer Science & Business Media.

Koellinger, P. (2008). The relationship between technology, innovation, and firm performance—Empirical evidence from e-business in Europe. *Research Policy, 37*(8), 1317–1328.

Milewski, S. K., Fernandes, K. J., & Mount, M. P. (2015). Exploring technological process innovation from a lifecycle perspective. *International Journal of Operations Production Management, 35*(9), 1312–1331.

OECD. (2005). *The measurement of scientific and technological activities: Guidelines for collecting and interpreting innovation data: Oslo manual* (3rd ed.). Paris: OECD.

Reguia, C. (2014). Product innovation and the competitive advantage. *European Scientific Journal, ESJ, 10*(10), 140–157.

Slack, N., Brandon-Jones, A., & Johnston, R. (2013). *Operations management* (7th ed.). London: FT/Prentice-Hall.

The Importance of Using Alternative Energy Sources Within a New Global Perspective

Mario F. Mello, Eudes V. Santos, Marcos M. Falkembach, Cristina Pasqualli and Michele Siben

Abstract The world has suffered from the exploitation of its natural resources and so the search for alternative sources of energy gains more and more space. These non-renewable alternative sources do not harm nature. Thus, within a context of new global perspectives, the improvement of the use of renewable energies by diversifying generation sources should be a constant challenge for architects, engineers and those professionals involved in the use of energy in buildings. The lack of an adequate project contributes to low energy efficiency of the building, consuming energy, often unnecessarily, and without concern for its generation. The use of bioclimatic strategies emerges as a fundamental instrument in the design of a good architectural project, foreseeing the intelligent use of natural resources and providing rationality in the consumption of renewable energies. Therefore, a natural thermal conditioning in dwellings, where this is possible, can bring new perspectives of rational use of energy. The general objective of the work is to demonstrate that it is possible to replace mechanical ventilation with the use of natural air conditioning, thus reducing the consumption of traditional electric energy. Such strategies are possible for use in both residential and industrial buildings.

Keywords Bioclimatic strategies · Natural thermal conditioning
Renewable energies

M. F. Mello (✉)
Escola de Engenharia, Universidade Luterana do Brasil—ULBRA, Santa Maria,
Rio Grande do Sul 97030-080, Brazil
e-mail: mariofernandomello@yahoo.com.br

E. V. Santos · M. M. Falkembach
Universidade Luterana do Brasil—ULBRA, Santa Maria,
Rio Grande do Sul 97030-080, Brazil

C. Pasqualli · M. Siben
Escola de Engenharia, Faculdade Meridional, IMED, Passo Fundo,
Rio Grande do Sul 995079-220, Brazil

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1 Introduction

The new global perspectives make us work with the problem of the energy crisis. Thermal conditioning of housing and industrial environments can be viewed under a new prism. Although the technology provides us with sophisticated equipment, it is possible to obtain favorable conditions to the built environment through simple but rational techniques that aim at taking advantage of the conditions of nature for environmental comfort.

Architecture and Engineering plays a major role in the use of new constructive techniques that favor natural energy sources. The lack of a suitable project can make a building a sick building, not simply because it generates a lot of problems, such as pollution, waste of natural resources, but also because it jeopardizes the health of the future occupants of the building. Today, many of the buildings designed deny the adequate use of materials and construction techniques with use of natural resources, including the thermal comfort of the building, generating great consumption of electric energy through air conditioners.

Given this context, it is the professional's premise to investigate bioclimatic and material conditions that fit the local reality and the new global perspectives of sustainable development, thus becoming an energy efficient construction. Not far away, it is necessary marketing strategies that promote the different publics to the use of the natural resources.

The present work will show that it is possible to use bioclimatic strategies through a building constructed with these new perspectives. The general objective of the work is to demonstrate that it is possible to replace mechanical ventilation with the use of natural air conditioning, thus reducing the consumption of traditional electric energy. Such strategies are possible for use in both residential and industrial buildings.

2 Theoretical Background

2.1 Domestic Supply of Electricity in Brazil, by Source

The generation of electric energy in Brazil in public service and self-producers plants reached 581.5 TWh in 2015 according to the Energy Research Company (2016) linked to the Ministry of Mines and Energy. Public utility power plants with 83.4% of total generation remain the main contributors.

According to EPE (2016), electric generation from non-renewable sources represented 26% of the national total, demonstrating a large space for growth of renewable energy. Figure 1 shows the internal supply of electric energy, by source, in Brazil. It is possible to notice the great predominance of the energy generated by hydroelectric plants, with 64.07% of the total generated in the country.

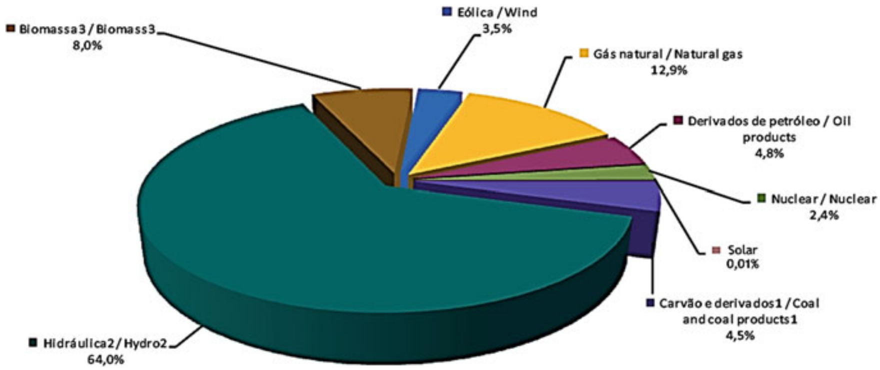

Fig. 1 Internal offer of energy. *Source* EPE (2016)

2.2 *Natural Thermal Conditioning*

According to Costa (2012), in order to study the relationships that a man maintains with the natural environment in which he lives by seeking the balance by which everything that is consumed is constantly reestablished, in this continuous process of destruction and renewal is that the possibilities for improvement are opened, for the evolution.

Costa (2012) emphasizes that ecological architecture is the art of building dwellings, taking advantage of the immediate resources provided by nature itself, without altering its equilibrium.

In Brazil there is a bioclimatic zoning, which according to NBR 15.220-3, divides the country into eight homogeneous zones with respect to the climate. The dwelling, object of this study, is inserted in the bioclimatic zone 2 (Z2).

Therefore, the proper use of information from a particular climatic region is fundamental for architects and engineers in the search for a better use of natural thermal conditioning.

For Costa (2012), the main purpose of housing is the protection of man against the aggression of the environment, against the discomfort caused by nature itself with its meteorological phenomena.

Still for Costa (2012), the variation of the internal temperature of a house is due to numerous factors, such as:

(a) Daytime sunshine which contributes a substantial part of the heat entering the dwelling, in particular through the transparent surfaces and cover;
(b) The internal heat generated by people and equipment;
(c) Heat exchanges by heat transfer, both from outside to inside (during the day) and from inside to outside (at night), through surfaces that limit the inhabited environment;
(d) The heat exchanges of heating (day) or cooling (night) provided by the ventilation air.

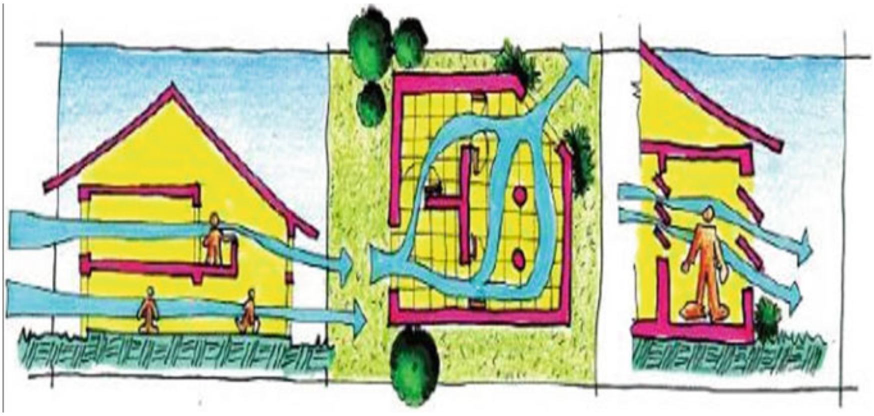

Fig. 2 Illustration of natural air circulation. *Source* Lamberts et al. (2014)

2.3 Bioclimatic Ventilation Strategy

According to Lamberts et al. (2014), the elements and bioclimatic strategies to be implemented in the architectural project will depend on a bioclimatic analysis and field study. For each bioclimatic zone there are some possible strategies to be employed in the design of the building.

According to Lamberts et al. (2014), when this strategy becomes necessary to the project, it can be explored through solar shape and orientation in order to maximize the building exposure to summer breezes. The spaces must be fluid and allow air circulation between all environments, as shown in Fig. 2.

Another practice is to promote vertical ventilation to remove hot air, which accumulates in the highest parts inside the building, through an upward airflow generated by openings at different levels.

3 Methodological Procedures

For the development of the present study, a study was carried out in three stages. The first stage consisted in the search for a theoretical reference, consecrated and updated on the subject proposed here. In the second stage, field studies were carried out, analyzing new constructive perspectives to identify and raise the practices used by the building under study. Finally, in the third stage, the data collected were analyzed and demonstrated through the example of a building in the city of Itaara, Rio Grande do Sul state, Brazil, that it is possible to use natural thermal conditioning using the tunneling of the air.

The study has an exploratory-descriptive character regarding the objectives that, according to Gil (2008), provides greater familiarity with the problem and describes the characteristics of certain phenomena.

The study was carried out from October to December 2016. It will be demonstrated, through a simulation, the possible cost reduction of electric energy once the rooms (used for simulation) do not have air-conditioning. Available data from the manufacturer of air-conditioners were utilized as well as the rates charged by the local electricity provider company.

4 Results

4.1 Verification of Bioclimatic Strategies for the City of Itaara

The Brazilian city of Itaara/RS state is located in bioclimatic zone 2 (Z2), according to NBR 15.220-3. Through the program ZBBR—Bioclimatic Classification of Brazilian Municipalities—version 1.1 (2004), the recommendations for this bioclimatic zone were verified, according to Fig. 3.

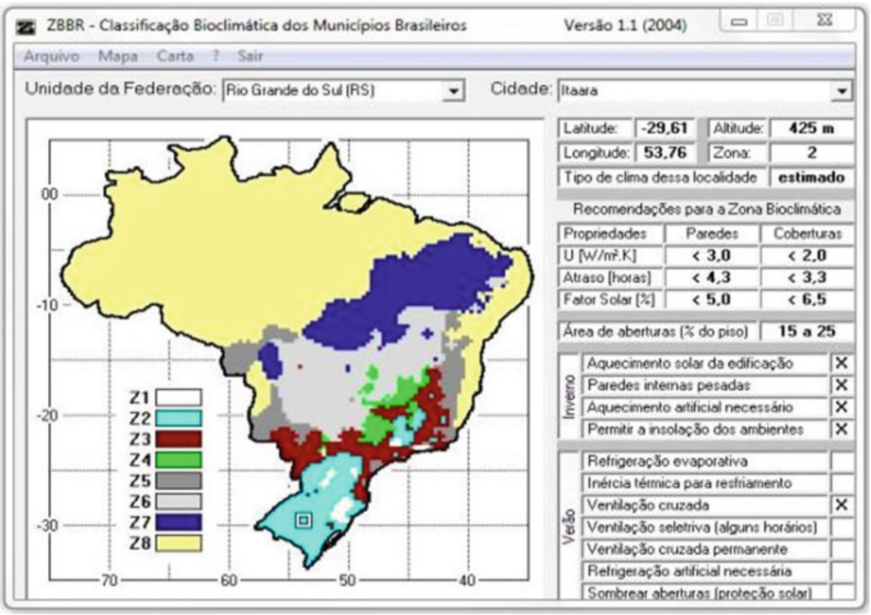

Fig. 3 Recommendations for the area where the dwelling is located

4.2 On-Site Visit and Identification of the Bioclimatic Strategies Applied in the Construction

In the visit to the building constructed in the Brazilian city of Itaara/RS state, it was possible to verify the application of some bioclimatic strategies that are in agreement with Lamberts et al. (2014), also described in accordance with ABNT (2005) NBR 15.220-3 and verified in the Program ZBBR—Bioclimatic Classification of Brazilian Municipalities—version 1.1 (2004). These include cross ventilation and the use of heavy inner walls.

The four floor building has 1600 m^2 and is situated in a rural area of the municipality. In the basement there is a library, laundry, storage space and garage. On the ground floor, the living room, the dining room, the meeting room, the chapel, the kitchen, an office, an outbuilding with a living room, a bedroom and a bathroom, a small meeting room and toilets. The second and third floors consist of 16 bedrooms in total, and each room has three beds and a bathroom. The building is installed in order to take advantage of the natural unevenness of the terrain according to Fig. 4.

In order to minimize the expenses with electric energy, it was sought to capture natural air to keep the building thermally comfortable. However, to conserve the building internal temperature, it was built using double walls with a 2 cm air layer between them and well-fenced double glazing. The natural ventilation comes from a tunnel built of basalt stones below the basement. The tunnel is 25 m long, 2.80 m

Fig. 4 Researched building

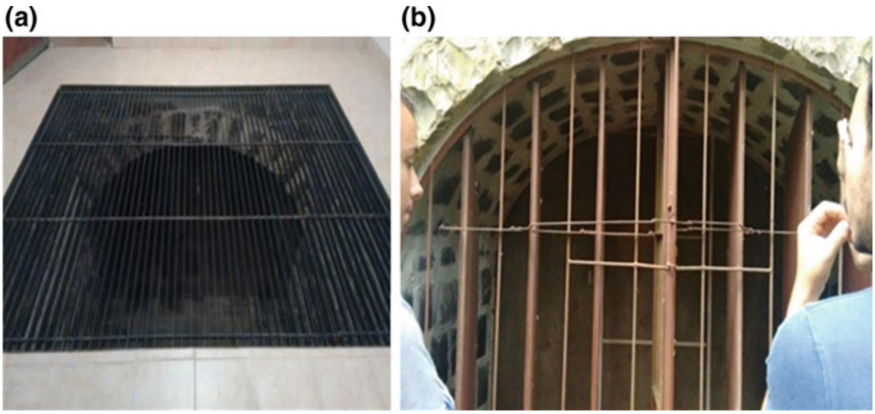

Fig. 5 Wind tunnel

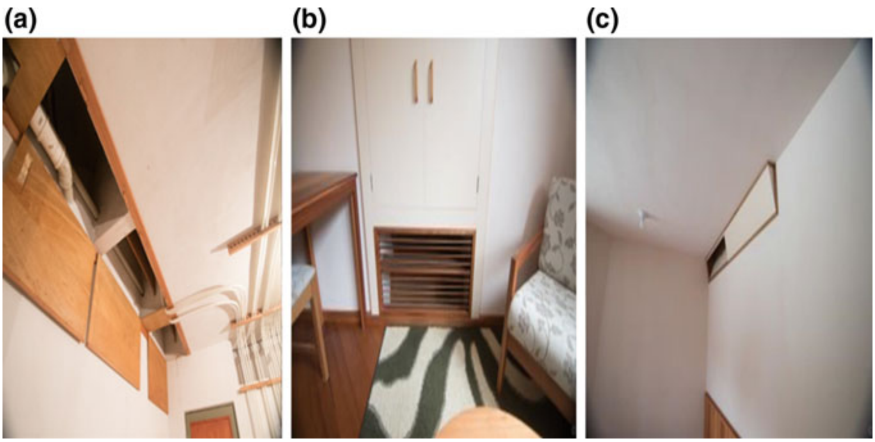

Fig. 6 Ducts for vertical ventilation

wide and 1.80 m high. This tunnel has the function of capturing the natural air of the forest and leading it to a large opening in the subsoil, according to Fig. 5a. In order to control air collection, both in summer and in winter, the tunnel has a manual closing, as shown in Fig. 5b.

In order to obtain cross ventilation and distribute the natural air to the dormitories, located on the second and third floors, small ducts with openings directed towards the exit of air of the tunnel were proposed to capture this air and to consume it to all the dormitories, according to Fig. 6a. The natural air collected by these ducts is introduced into the dorms through openings close to the floor, shown in Fig. 6b, by drawing hot air through openings arranged in the upper part of the room, Fig. 6c, but constructed on the opposite side for cross ventilation.

This movement of the air happens due to an opening in the cover (below the tiles), that gives to the system a difference of pressure, driving all the hot air outside of the building.

The research identified that, on days where the ambient temperature outside the building exceeds 30 °C, the indoor environments remain thermally comfortable, providing a temperature around 25 °C due to vertical ventilation resulting from the wind tunnel, double walls and double glasses. Along with these bioclimatic strategies cited, the building is able, according to the owner, to reduce the consumption of electric energy and to keep the environments always healthy, avoiding what we call sick building syndrome.

Together with the research, it was verified that the bioclimatic strategies are of extreme importance to the architectural design and provide energy efficiency to the building, and can even be used in commercial and industrial buildings.

4.3 *Simulation of Partial Consumption*

Considering that, with these bioclimatic strategies, there is the possibility of not using conventional air conditioners, a simulation was performed with the objective of identifying the possible reduction in the consumption of electric energy. For the purpose of the calculation, it was considered a 12.000 btus air conditioner in each of the 8 possible rooms to receive the appliance. It was also considered an average daily use of 8 h in all seasons of the year. The consumption data of the device were collected from the information provided by the manufacturer. The value of electric energy consumption (kW/h) is made available by the local provider.

The consumption, according to the manufacturer of the air conditioners, is 3516 Wh (Watts/h), which corresponds to 3.52 kWh. On the other hand, the value of kWh supplied by the concessionaire, in the studied period, is R$ 0.47202. The data used for the simulation are described in Fig. 7.

Calculation equations:

Consumption in kW = Equipment power x hours used × days in use
Consumption in kW = 3.52 × 8 × 360 = 10.137.6 kW/year
Value of consumption per appliance = consumption in kW/year × tariff
Value of consumption per appliance = 10,137.6 kW/year × 0.47202
Value of annual consumption = R$ 4785.14

Simulation	Unit
Number of appliances	8
Hours of usage per day	8 hours
Days on a month	30 days
Consumption kW per day	3,52 kW per day
Electric energy rate 1kWh	R$ 0,47202

Fig. 7 Data table used for the simulation

Consumption in kW per appliances per year	Number of appliances	Total year consumption in kW	Rate of electricity energy in R$	Total value of the year consumption in R$	Total value of the year consumption in US$*
10.137,6 kW	8	121.651,20 kW	0,47202	57.421,79	17.618,91

* Price of the dollar practiced by the Central Bank of Brazil on 12/30/2016

Fig. 8 Simulation summary table

Figure 8 shows the significant savings with the use of conventional electric energy, opting for bioclimatic strategies. Together with the use of natural ventilation is recommended the use of walls and double glazing for better energy efficiency. When the natural ventilation is provided, 121,651.20 kW/year is saved, which means a reduction of costs of conventional electric energy, in the order of US $ 17,618.91, per year.

5 Conclusion

The use of natural thermal conditioning within the context of new global perspectives should receive greater attention from architects and engineers in order to contribute to the preservation of the environment and consequent energy savings. Integrating man and the environment through alternative sources of energy is an objective that requires adequate solutions in the process of creation and execution in civil construction. In view of this, this research brings as a contribution the identification of bioclimatic strategies used in a building in the city of Itaara/RS and how they can improve the thermal comfort of users and consequent energy savings. Even with the limitations that the present study presents, it is believed that it will serve both for the academic environment and also to make professionals and users aware of the importance of using bioclimatic strategies in new building projects.

References

Associação Brasileira de Normas Técnicas—ABNT. (2005). NBR 15220-3 - Desempenho térmico de edificações. Rio de Janeiro.

Costa, E. C. (2012). Arquitetura ecológica: condicionamento térmico natural. 5 reipr. São Paulo: Blucher.

Empresa Brasileira de Pesquisa Energética—EPE (2016). *Brazilian energy balance 2016: year 2015*. Rio de Janeiro: Disponível em: https://ben.epe.gov.br/downloads/Relatorio_Final_BEN_2016.pdf. Acesso em: janeiro/2017.

Gil, A. C. (2008). *Como elaborar projetos de pesquisa* (4 ed.). São Paulo: Atlas.

Lamberts, R., Dutra, L., & Pereira, F. O. R. (2014). Eficiência Energética na Arquitetura (3ª ed). Rio de Janeiro.

Strategies Adopted by Social Enterprises to Overcome Operations Resources Constraints: The Case of Vintage for a Cause

L. Ávila, M. Amorim and L. Ferreira

Abstract Hybrid organizations are emerging in the organizational landscape, integrating social and commercial objectives into the same strategy. This paper aims to address the strategies adopted by social enterprises (a particular case of hybrid organization), serving target groups who cannot pay for services and products as common customers, to overcome operations resources constraints. Based on the case of Vintage for a Cause the authors identify the incorporation of external resources and reputation through partnerships, the recruitment of beneficiaries as volunteers to the workforce and the diversification of income generating activities as some of the strategies that can be followed by organizations sharing the same particularities.

Keywords Hybrid organizations · Social enterprises · Operations strategy Operations resources constraints · Vintage for a cause

1 Introduction

In recent years, hybrid organizational models have been gaining ground in the business landscape, offering value propositions that combine social and economic goals, blending characteristics from different sectors (Ebrahim et al. 2014; Jäger and

L. Ávila · M. Amorim (✉)
GOVCOPP & Department of Economics, Management, Industrial Engineering and Tourism, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal
e-mail: mamorim@ua.pt

L. Ávila
e-mail: liliana.avila@ua.pt

L. Ferreira
Department of Mechanical Engineering, University of Coimbra, Rua Luís Reis Santos Pinhal de Marrocos, 3030-788 Coimbra, Portugal
e-mail: luis.ferreira@dem.uc.pt

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Schröer 2013). This is happening due to diverse contextual circumstances, among which financial constraints and economic crisis rank as key drivers. In recent years non-profit organizations have been forced to find alternative ways to fund and to sustain their social activities, and to reduce their dependency from the State, whom in many cases used to be the main funder (Battilana and Lee 2014). Moreover, as private companies have to address consumers that are increasingly informed, and consequently more demanding, they are being pressed to adopt more socially and environmentally responsible practices.

Thus, new organizational models are emerging from different sectors, pursuing social and economic goals simultaneously, the reason why they are called "hybrid". Social enterprises are an example of a hybrid form, although there are many possibilities of hybrid organizing in the continuum between traditional non-profit and for-profit (Wilson and Post 2011). Hybrid organizations are attracting a growing interest among academics and practitioners (Doherty et al. 2014). To date, the literature on hybrid organizations has focused on the definition and identification of the particularities of such organizations.

Hybrid organizations face many challenges once they try reconcile social and economic concerns under a common organizational and operational system. Resource management is a key issue for these organizations because they often serve disadvantaged groups that are not able to pay for products or services as common customers. There seem to be enough arguments to sustain that hybrid organizations can benefit from the prevalent knowledge in operations management and strategy and that there is space to develop new knowledge concerning the operational organization of the activities of such organizations. What are the strategies adopted by hybrid organizations to manage limited resources in order to maximize the social and economic impact they are generating? This paper aims to contribute to answer this question, building on the example of Vintage for a Cause, a social enterprise based on Porto (Portugal). The paper is structured as follows: first, in the background section, the main concepts related to operations management and strategy are presented, with a particular regard to the operations resources perspective, and, then, social enterprises are introduced as hybrid organizations; second, Vintage for a Cause is introduced and some of the strategies adopted by it to overcome operations resources constraints are discussed; third, conclusions are drawn.

2 Background

2.1 Operations Management, Strategy and Resources

Operations strategy is a well-explored and mature topic within the operations management literature. According to an exhaustive historical analysis of articles conducted by Rungtusanatham et al. (2003), operations strategy has emerged among the most addressed topics, standing out as showing fastest ascendancy to prominence in the literature on operations management. This fact demonstrates the importance of the decision making concerning the allocation of resources for supporting infrastructure and production.

Operations strategy is defined by Slack et al. (2001) as '*the pattern of strategic decisions and actions which set the role, objectives and activities of operations*'. In other words, it is a set of structural and infrastructural decisions made in order to achieve a competitive advantage such as cost, quality or flexibility (Díaz Garrido et al. 2007). The effects of operations strategy and decisions on firm's performance have been emphasized in the literature by several authors (Díaz Garrido et al. 2007; Espino-Rodriguez and Gil-Padilla 2014).

Different perspectives can be used to define an operations strategy. Each perspective has different starting points for making operational decisions. On the one hand, there are the top-down and the bottom-up perspectives, using the business strategy and the day-to-day experience as basis to set up the operations strategy, respectively. On the other hand, there are the other two perspectives based on market requirements and operations resources (Slack et al. 2001). The operations resources perspective in particular focus on operations resources (i.e., transforming and transformed resources), capabilities and processes to make strategic decisions (Gagnon 1999). According to this perspective, resources and capabilities are a source of competitive advantage and, therefore, they should be rare and hardly imitable by competitors.

Hybrid organizations are challenging the prevalent knowledge on operations management. There are some authors who argue that social enterprises utilize resources in an innovative manner in order to achieve a competitive advantage (Roy and Karna 2015). However, Glavas and Mish (2014) suggest that those organizations aiming to become more responsive ecologically and socially while prospering economically, they are more focused on pursuit a collaborative advantage instead a competitive advantage. Most of them strive to have resources that are sustainable and therefore imitable, commonly found and substitutable. This is important to assure that the model is scalable and easily replicable in other contexts to mitigate the social problem it aims to respond to.

2.2 *Hybrid Organizations: The Particular Case of Social Enterprises*

Social enterprises are organizations that respond to social issues through market approaches, pursuing social and economic aims simultaneously (Battilana and Lee 2014). They are positioned along the spectrum between traditional non-profit and traditional for-profit organizations as they combine characteristics from both sides (Neck et al. 2009; Wilson and Post 2011). Thus, a wide range of business models can be placed into this spectrum. In some countries, due to the lack of a legal framework adapted to the specificities of social enterprises, they are forced to develop their activities as associations, cooperatives or even as commercial businesses. However, regardless the legal form they choose to adopt, it is believed that main difference between social enterprises and other kind of organizations is the principles they follow. Social enterprises are different from socially responsible businesses, because the latter put the generation of profits and its distribution to shareholders as core priorities. Furthermore, social enterprises also differ from non-profit organizations running commercial activities as a way to get additional funds. Therefore, a social enterprise should have a social concern clearly presented in its mission statement and should generate great part of their revenues through the conduction of commercial activities. This contributes to ensure its financial sustainability in the long-term. Profits, if they exist, should be reinvested to grow the organization, scaling the social impact (Yunus 2011).

The hybrid nature of social enterprises make them fragile organizations, facing the risk of internal tensions and mission drift (Ebrahim et al. 2014; Santos et al. 2015). In the last years, research has been published identifying some critical domains where they were reported internal tensions concerning, for example, governance, human resources management and performance measurement issues. They are somewhat related with some decision areas usually considered in the definition of an operations strategy.

Because most of them serve disadvantage groups, to be successful social enterprises need to do a great job managing limited resources. Therefore, the attainment of effective operations management must be at the core of their priorities. What strategies do they adopt to overcome operations resources constraints and to generate social and economic value? The next section introduces the example of Vintage for a Cause and analyses the strategies embraced by its founders and some of their consequences.

3 Strategies Adopted by Social Enterprises to Overcome Operations Resources Constraints—The Case of Vintage for a Cause

In this section, some of the strategies adopted by social enterprises to overcome operations resources constraints are identified by analysing the case of Vintage for a Cause. The paper refers to a single case study as way to deeply understand what were the benefits and some of the consequences arising from each one of those strategies. Data collection comprised in-depth interviews conducted with the founders of Vintage for a Cause and different stakeholders such as beneficiaries, funding institutions and other partners, as well as some visits and the participation in some activities organized by Vintage for a Cause.

3.1 Vintage for a Cause

Vintage for a Cause was born in a postgraduate program in Social Entrepreneurship and Innovation promoted by the Portuguese Social Entrepreneurship Institute in 2012. The postgraduate program was organized in some seminars and a boot camp for the development of projects. The founders of Vintage for a Cause met for the first time in this context and developed the idea that would be the winner of the program.

The mission of Vintage for a Cause is to promote the active aging, personal development, interpersonal relationship and social inclusion of women over 50 with no professional activity. It is a sewing club where these women transform old clothing into new clothing with a vintage inspiration and unique design, supported by professional fashion designers. The clothes are donated and when transformed, they are sold in the online shop of Vintage for a Cause and some stores in Porto, where it is based. There are weekly ateliers (three hours) where the seam is the pretext to "*transform lives through the transformation of clothing*" (the motto of *Vintage for a Cause*). The participation in these workshops is free. Ordinary women have the opportunity to become unlikely fashion designers, transforming themselves and their lives. This informal and creative context, help these women developing new social relationships as well as acquiring new skills and new life goals. One year after implementing the pilot with ten women, the ateliers were attended by 84 women aged between 52 and 88.

3.2 Strategies Adopted by Vintage for a Cause to Overcome Resources Constraints

3.2.1 Incorporating External Resources and Gaining Reputation Through Partnerships

For many social entrepreneurship initiatives, such as Vintage for a Cause, it is difficult to have their own resources to run their activities. They have to find alternatives to get access to the resources they need to sustain their operations. The establishment of networks and partnerships with other organizations is crucial to access external resources the organization is not able to afford (Phillips et al. 2014).

In the particular case of Vintage for a Cause, partnerships allowed it to rent a space at a lower cost (rented by the city council) although, according to one of the founders, partnerships have been particularly important to compensate the existence of few paid human resources and little specialized. For instance, the website was designed by a young digital marketing agency who wants to promote its work, the accountant provides its services free of charge and there are also fashion designers available to teach some techniques and support the creative work in the atelier in a volunteer basis. By accessing these external resources, Vintage for a Cause is reducing its costs but it is also improving its reputation and showing to financing institutions that it is able to mobilize resources from the community. This is often seen as a good indicator and may open doors for the concession of some grants which can be used to cover other operational costs (e.g. materials, electricity, water, etc.). However, relying on the resources of others may also lead to some constraints and difficulties to grow the organization. It is not well positioned to demand the provision of a professional service once the sharing of resources is based on the goodwill.

3.2.2 Recruiting Beneficiaries as Volunteers to the Workforce

Regarding human resources practices, often social enterprises have a workforce composed of both paid workers and volunteers (Royce 2007) as happens in many non-profit organizations.

Vintage for a Cause is not an exception in this matter. As aforementioned, it has the support of some fashion designers working as volunteers. However, a large part of its workforce is comprised of beneficiaries (i.e. women over 50 with no professional activity), who attend the ateliers where clothes are transformed. This model created by the founders of Vintage for a Cause presents many strengths. They give to those women the opportunity to attend the weakly workshops for free, transforming their lives through the transformation of clothes, which are sold to sustain the operations of the organization. This way they differentiate from their competition through an innovative offer that have no costs to the beneficiaries. At the same time, they reduce their costs with human resources and have a direct contact with beneficiaries, directly impacting their lives. In some cases, Vintage for a Cause was not just a vehicle for the establishment of new relationships but also for acquiring new skills and new life goals. Some beneficiaries returned to work because they realized they still able to exercise a professional activity.

Although this model has proven to be effective at an early stage, later, founders were confronted with some difficulties to maintain the motivation and participation levels in the activities, since the participation is not mandatory. They were forced to rethink their strategy and make an effort to better define the role of each beneficiary and engage them more deeply in the activities.

3.2.3 Diversifying Income Generating Activities

Battilana et al. (2012) define the hybrid ideal as a fully integrated organization, where everything is done in order to produce social value and commercial revenue. Thus, mission and profit aims are part of the same strategy. However, as aforementioned, following this fully integrated approach is a big challenge for many organizations who serve disadvantaged groups that are not able to pay as ordinary customers to get access to their products and services. This way, these organizations are forced to follow less integrated approaches, conducting commercial activities (related or not to the mission) that are crucial for sustain their operations.

Therefore, if social enterprises do not manage to have access to all the operations resources they need through the establishment of partnerships with other organizations or it does not make sense for their mission to involve volunteers in their operations, maybe they should consider increase their income generating activities.

For instance, Vintage for a Cause decided to diversify its income generating activities by creating some thematic workshops organized occasionally for the general public and available in a short period of time (e.g. two weeks). In these workshops participants learn sewing and other techniques related to the transformation of clothes. In some cases, they happen at the same time of the ateliers, giving to the participants the opportunity to interact with the beneficiaries who attend the weekly ateliers. This was a way to increase revenues as well as to reach new target groups, disseminate the project and the concept, improving its reputation among the community and, perhaps, reaching new beneficiaries.

4 Conclusions

Studying the prevalent literature on operations management and strategy and transferring that knowledge already extensively applied to manufacturing and service firms to the emergent fields may represent a valuable contribute to the generation of new insights. Hybrid organizations, and social enterprises in particular, is a relatively new field that is posing many challenges to practitioners and claims for new research insights. The effective mobilization and management of operations resources is a critical issue for such organizations to ensure they achieve the social impact aimed, through a model that is sustainable and scalable.

This paper aimed to advance the knowledge on the operations management of social enterprises by analysing how Vintage for a Cause has dealing with resource constraints typically faced by such organizations. The authors decided to refer to a single case study because it allowed to deeply discuss the effects that each strategy had in the organization. They believe the way Vintage for a Cause has surpassed resources constraints has much in common with other social enterprises with whom it shares some particularities. These strategies lead to challenges in other domains within operations, for instance in terms of risk management, quality and performance management due to the dependence on external resources and volunteer work. If more cases were used, the analysis would be more superficial. This approach presents limitations in terms of the generalization of the results of the analysis although it can be argued that is a good starting point to take the discussion to the next level.

References

Battilana, J., & Lee, M. (2014). Advancing research on hybrid organizing—Insights from the study of social enterprises. *Academy of Management Annals, 8,* 397–441.

Battilana, J., Lee, M., Walker, J., & Dorsey, C. (2012). In search of the hybrid ideal. *Stanford Social Innovation Review, 10,* 51–55.

Díaz Garrido, E., Martín-Peña, M. L., & García-Muiña, F. (2007). Structural and infrastructural practices as elements of content operations strategy. The effect on a firm's competitiveness. *International Journal of Production Research, 45,* 2119–2140.

Doherty, B., Haugh, H., & Lyon, F. (2014). Social enterprises as hybrid organizations: A review and research agenda. *International Journal of Management Reviews, 16,* 417–436.

Ebrahim, A., Battilana, J., & Mair, J. (2014). The governance of social enterprises: Mission drift and accountability challenges in hybrid organizations. *Research in Organizational Behavior, 34,* 81–100.

Espino-Rodriguez, T. F., Gil-Padilla, a. M. (2014). The structural and infrastructural decisions of operations management in the hotel sector and their impact on organizational performance. *Tourism and Hospitality Research, 15*, 3–18.

Gagnon, S. (1999). Resource-based competition and the new operations strategy. *International Journal of Operations & Production Management, 19,* 125–138.

Glavas, A., & Mish, J. (2014). Resources and capabilities of triple bottom line firms: Going over old or breaking new ground? *Journal of Business Ethics, 127,* 623–642.

Jäger, U. P., & Schröer, A. (2013). Integrated organizational identity: A definition of hybrid organizations and a research agenda. *VOLUNTAS: International Journal of Voluntary and Nonprofit Organizations, 25,* 1281–1306.

Neck, H., Brush, C., & Allen, E. (2009). The landscape of social entrepreneurship. *Business Horizons, 52,* 13–19.

Pache, A.-C., & Santos, F. (2012). Inside the hybrid organization: Selective coupling as a response to competing institutional logics. *Academy of Management Journal, 56,* 972–1001.

Phillips, W., Lee, H., Ghobadian, A., O'Regan, N., & James, P. (2014). Social innovation and social entrepreneurship: A systematic review. *Group & Organization Management, 40,* 428–461.

Roy, K., & Karna, A. (2015). Doing social good on a sustainable basis: Competitive advantage of social businesses. *Management Decision, 53,* 1355–1374.

Royce, M. (2007). Using human resource management tools to support social enterprise: Emerging themes from the sector. *Social Enterprise Journal, 3,* 10–19.

Rungtusanatham, M. J., Choi, T. Y., Hollingworth, D. G., Wu, Z., & Forza, C. (2003). Survey research in operations management: Historical analyses. *Journal of Operations Management, 21,* 475–488.

Santos, F. M., Pache, A.-C., & Birkholz, C. (2015). Making Hybrids Work: Aligning business models and organizational design for social enterprises. *California Management Review, 57,* 36–58.

Slack, N., Chambers, S., & Johnston, R. (2001). *Operations managment* (3rd ed.). Harlow: Financial Times Prentice Hall.

Smith, W. K., Gonin, M., & Besharov, M. L. (2013). Managing social-business tensions. *Business Ethics Quarterly, 23,* 407–442.

Wilson, F., & Post, J. E. (2011). Business models for people, planet (& profits): Exploring the phenomena of social business, a market-based approach to social value creation. *Small Business Economics, 40,* 715–737.

Yunus, M. (2011). *A empresa social*. Lisboa: Editorial Presença.

Developing a Scale to Measure Quality in Public Transport Services

J. C. V. Soares, V. F. Paula, V. B. Brandão, M. A. de Souza and A. S. S. Neto

Abstract Nowadays the service sector is a relevant segment to the countries around the world. Especially referent to public transportation service, it is important to highlight that it is essential for the economy and welfare of the society. In this sense, the quality and the customer´s satisfaction are important factors in this sector. Thus, it seems to be pertinent to measure these factors. Then, the objective of this paper is to describe the scale construction process, whose purpose is to measure and evaluate the quality of the public transportation service according to the customer´s satisfaction. Further, this work seeks to present the preliminary results obtained from the application of this scale. The scale in discussion was published in ENCOBEP 2016 (Encontro do Centro-Oeste Brasileiro de Engenharia de Produção), but after this event, the scale was analyzed by authors of this paper to get the third version. This version was applied in a sample of 146 customers of the public transportation service and the quantitative data were treated statistically. The results showed that the reliability of the scale is acceptable and the conclusion is that the customers are unsatisfied with the public transportation services.

Keywords Quality · Service · Public · Transport · Scale

J. C. V. Soares · V. F. Paula · V. B. Brandão · M. A. de Souza · A. S. S. Neto (✉)
Curso de Engenharia de Produção, Faculdade de Ciências e Tecnologia, Câmpus Aparecida de Goiânia Regional Goiânia, Universidade Federal de Goiás, Rua Mucuri, s/n, Área 3, (Campus da UEG/UFG), Setor Conde dos Arcos, Aparecida de Goiânia, GO 74968-755, Brazil
e-mail: agenor07@hotmail.com

J. C. V. Soares
e-mail: j-cvs@hotmail.com

V. F. Paula
e-mail: v-depaula@hotmail.com

V. B. Brandão
e-mail: vbbrandao21@gmail.com

M. A. de Souza
e-mail: mayaraalves50@gmail.com

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1 Introduction

Currently, the service sector is an important segment and brings significant benefits for a country. These benefits, such as employability, have a major influence on the gross domestic product. In this sense, it was observed that the service sectors are very essential for the economy of a country, survival and prosperity of people. Regarding to quality of services, Brown and Bitner (2007) highlight that the fast development and competition of service industries, in both developed and developing countries, has became essential for companies to measure the quality of its services.

Additionally, the evaluation of the customer' satisfaction consists in an important object of study. According to Pantouvakis (2010) the identification of service attributes is necessary for some effective use of resources, implying in the services quality.

Extending the quality of services for public transport, Gebauer et al. (2010) concluded that the focus of public-transport operators should be on the quality of provider-consumer interactions, the provision of innovative experience environments, and the development of experience networks. According to Pérez et al. (2007) the introduction of "quality management" has become increasingly common in facing the challenges posed by economic and political pressures on public expenditure. Such "quality initiatives" have been linked to the commercialisation of public services and growing recognition of the needs and demands of sovereign customers in the marketplace (Ancarani and Capaldo 2001).

However, Friman et al. (2001) argue that the search has concentrated on the private sector. A review of the studies that exist on the public sector reveals that there has been few published research on public transport and users' satisfaction with the services they receive. Some studies have explored the technical aspects of the service, but there has been little research on the important psychological and social aspects of consumer satisfaction (Everett and Watson 1987), although recently the studies about public services quality have become increasingly common.

2 Objectives

The objective of this paper is to describe the scale construction process, whose purpose is to measure and evaluate the quality of the public service transport according to the customer´s satisfaction. Additionally, this research seeks to present preliminary results obtained from the application of this scale.

3 Methods

Regarding to the collect data process, it is important to highlight that were collected primary and secondary data and also qualitative and quantitative data. The secondary data were obtained from the investigation of the literature in order to generate the first version for the construction of the scale. Primary data were obtained firstly from a focus group. In this process, it was used the first version of the scale to obtain the second version. Then, the authors of this paper analyzed the second version and obtained the third version of the scale. Finally, the third scale was applied in a sample of 146 customers of the public transportation service (pre-test) from April 2016 to February 2017.

It is important to highlight that the scale in discussion was published in ENCOBEP 2016 (Encontro do Centro-Oeste Brasileiro de Engenharia de Produção), Soares et al. (2016). However, after this event, the scale was analyzed by authors of this paper to get the third version. So, this work describes and analyzes the scale process development after ENCOBEP 2016.

The quantitative data were treated statistically. It was obtained parameters inherent to descriptive statistics, particularly measures of central tendency and dispersion, such as average, standard deviation and coefficient of variation. Finally, considering the scale reliability analysis, were calculated the Cronbach's Alpha coefficient.

4 Results and Discussions

4.1 The Scale Development Process

In a first moment, the scale was developed by the authors taking as background the literature researched. After that, it was formulated the second version of the scale based on a focus group. These processes are described in Soares et al. (2016). After the second version, the authors analysed the scale and some changes were made in order to improve it, then, the third version was created. The changes were performed referring to the general questions of the scale (Part 1), so that questions were remade, in order to clare, direct and simplify for the interviewee, and also was added other question regarding to the location of the interview.

The third version of the scale is shown follow in Figs. 1 and 2 specially the parts 1, 2, 3 and the attributes/constructs respectively.

Research on the perception of the users about the quality of the services provided in the area of public transport (third version)

User,

This questionnaire comes from research that is being performed to evaluate the satisfaction/dissatisfaction on the quality of transport services of the municipality of Aparecida de Goiânia from the "expectation/perceptions" of the users of such services. This research is linked to the Industrial Engineering course Special Academic Unit of Sciences and Technology of Aparecida de Goiânia Campus of the Federal University of Goiás.

Part 1 – General data

1- **Has any disabilities?**

( ) Yes ( ) No

2- **Genre**

( ) Female
( ) Male

3- **Age**

( ) Up to 18 years
( ) 19 to 35 years
( ) 36 to 50 years
( ) 51 to 60 years
( ) Over 60 years

4- **Frequency of use of public transportation**

( ) Daily
( ) Often
( ) Sometimes
( ) Rarely

5- **Reasons for use**

( ) Work
( ) Studies
( ) Health
( ) Others

6- **What is your degree of education?**

( ) First degree incomplete (basic education)
( ) Incomplete high school (high school)
( ) Complete high school (ensino médio)
( ) Incomplete higher education
( ) Complete higher education

7- **Place of interview:**

( ) Veiga Jardim
( ) Araguaia
( ) Vila Brasília
( ) Garavelo
( ) Cruzeiro

Parte 2 – Expectations

User,

This part of the questionnaire is part of a survey to be carried out on "**expectations**" of users of public transport in the city of Aparecida de Goiânia/GO. That way, in this step, it is a rating of "**1 to 5**" in which:

1	2	3	4	5
No importance	Little importance	Moderate importance	Important	Very important

Parte 3 – Perceptions

User,

This part of the questionnaire is part of a survey to be carried out on "**perceptions**" of users of public transport in the city of Aparecida de Goiânia/GO. That way, in this step, it is a rating of "**1 to 5**" in which:

1	2	3	4	5
Very dissatisfied	Dissatisfied	Indifferent	Satisfied	Very satisfied

Fig. 1 Scale—parts 1, 2 and 3

ACESSIBILITY	
1- The distance between the points must meet the interests of all passengers.	
2- The points of sale and marketing of tickets must be safe and reliable.	
PRICE	
3- The price of tickets should not be abusive, but enough to provide a quality service.	
FREQUENCY	
4- The time between buses of the same line should be adequate according to the flow of passengers.	
REABILITY	
5- The bus must be punctual.	
TRIP´S TIME	
6- The time of the bus ride should be brief.	
BUSLOAD	
7- The buses should not be crowded.	
SECURITY	
8- Public transport should provide security as accidents and assaults.	
9- The stop locations must be safe.	
VEHICLES CARACHTERISTICS	
10- The buses should offer a good conservation status, comfort and cleanliness.	
BUS STOP CARACHTERISTICS	
11- Terminals and stopping points must have good signage, coverage and seat.	
12- The stop locations must offer access to information about lines and timetables to users.	
CONNECTIVITY	
13- There must be a facility in exchange for buses and good integration between the lines.	
COURTESY/CUSTOMER SERVICE	
14- Drivers, tax collectors and other bus workers must show good behavior and good education.	
ROAD QUALITY	
15- The routes where the buses travel must be good condition.	

Fig. 2 Scale—attributes/constructs

4.2 Preliminary Results

The objective of this paper is also to measure and assess the satisfaction of the public transportation in Aparecida de Goiânia city. In this sense, according to Tse and Wilton (1988) the customer satisfaction is considered a function of the perceived performance relative to consumer's prior expectations. Conform to Grönroos (1984) the European tradition posits service quality as resulting from a comparison between the customer's expectations of the service and the customer's perception of the service actually received. Additionally Parasuraman et al. (1985) defined and conceptualized service quality as a form of attitude, which results from a comparison of customers' expectations with perceptions of performance.

So the Table 1 shows the values referent the expectative, perceptions, mean, standard deviation and coefficient of variation regarding to each attribute of the scale in discussion and the gap referent expectative and perception levels.

First of all, we can observe that to all attributes the expectations levels are largest that the perceptions levels. It means, in general, that customers are unsatisfied with the public transport services. Thus, based on Table 1 it is possible to observe that the largest gap is 3.096 and relates to the question 8—"Public transport should provide security as accidents and assaults", referent to construct "security". The second and the third largest gap are related to the questions 9—"The stop locations must be safe" and 7—"The buses should not be crowded", regarding to the

Table 1 Mean, standard deviation, coefficient of variation and gaps

No.	Mean score		Gap	Standard deviation		Coefficient of variation (%)	
	Expectation	Perception		Expectation	Perception	Expectation	Perception
1	4.22	2.58	1.64	0.93	0.97	22.01	37.44
2	4.61	2.52	2.09	0.76	1.12	16.39	44.49
3	4.72	1.96	2.76	0.64	1.08	13.57	54.91
4	4.50	2.000	2.50	0.80	0.95	17.75	47.71
5	4.69	2.31	2.38	0.68	1.13	14.56	48.96
6	3.73	2.30	1.43	1.11	1.02	29.82	44.31
7	4.45	1.60	2.86	0.80	1.05	17.91	66.06
8	4.77	1.68	3.10	0.61	0.98	12.73	58.53
9	4.73	1.71	3.01	0.65	0.97	13.73	56.55
10	4.58	2.12	2.47	0.69	0.99	15.11	46.61
11	4.51	2.16	2.35	0.79	1.06	17.50	49.15
12	4.52	2.10	2.43	0.80	1.10	17.66	52.36
13	4.40	2.40	2.00	0.79	1.12	18.00	46.75
14	4.41	2.69	1.72	0.79	1.05	17.99	39.16
15	4.51	2.35	2.17	0.74	0.98	16.50	41.71

constructs “security” and “busload” respectively. In other words, to these attributes there are the main dissatisfactions levels.

For the other hand, the three smallest gaps are identified to attributes 6—“The time of the bus ride should be brief”, 1—“The distance between the points must meet the interests of all passengers” and 14—“Drivers, tax collectors and other bus workers must show good behavior and good education” linked to constructs “trip’s time”, “accessibility” and “courtesy/customer service” respectively. It means that to these attributes the customers show the smaller dissatisfactions.

Specially to the expectations values, we can observe that the three largest values are respectively referents to attributes 8—“Public transport should provide security as accidents and assaults”, 9—“The stop locations must be safe”, linked to Security construct, and 3—“The price of tickets should not be abusive, but enough to provide a quality service”, regarding to price construct. It is important to say that high values referent to expectations mean great importance to the customers. So, these attributes (8, 9 and 3) are relevant to clients, but the performance (perception) relates these attributes are low if compared with other attributes. This finding is obviously worrying, because for these more important attributes, the management of public transport should prioritize actions in order to achieve the best performances.

Table 1 also shows that values referent to the variation coefficient (VC) are relatively low. In relation to the VC, it is important to emphasize that this information is a statistic unit that corresponds to the standard deviation in average’s percentage, being the statistic parameter mostly used by researches in relation to the accuracy quality of experiments (Amaral et al. 2007). Conform Gomes (2000), in the field experiments, if the coefficient of variation is less than 10%, the same is low, between 10 and 20% is median, between 20 and 30 is high and above 30 is considered too much high.

Shimakura (2011) underline that if we have low levels of VC this means that is more homogeneous data set. The VC is low when it is lower or equal 25%. However, this standard can be different according to the application. It is hard to classify a variation coefficient as low, median or high, according to Shimakura (2011), but this can be good when you compare two variables or two groups which are impossible to establish comparisons.

Therefore, according to Table 1 the values for the coefficient of variation (CV) are relatively low when the attributes of the user's expectation of public transport, however, these coefficients of variation becomes high when the attributes of the perception of users are taken into consideration.

The coefficient of variation for the expectation is on average 17.42%, the average perception increases to 48.98%. So, the values referent expectations are low or medium and the values of the perceptions are high. Starting from this principle, regarding to expectations values, most of its attributes presents moderate variation coefficient, since their values are between 10 and 20%. For the other hand, the mostly values referent the perceptions are high (above 35%), i.e. these perceptions, in terms of values, are more heterogeneous than expectations.

Finally referent to the scale reliability analysis were calculated the Cronbach's Alpha coefficient. The value found was equal to 0.808. It means that the reliability of the scale is acceptable. According to Malhotra (2001) the minimum value to be considered for this parameter is 0.60, for values lowers than it the reliability is considered weak.

5 Conclusion

The third version of the scale in construction was developed taking some suggestions from the interviewees and from the authors of this paper, mainly suggestions referent to the general questions of the scale (Part 1), in order to simplify for the interviewee process. This version was applied and tested in a sample of 146 customers of the public transportation service from April 2016 to February 2017. The results showed that the reliability of the scale is acceptable.

In relation to the preliminary results (descriptive analyses) we can conclude that customers are unsatisfied with the public transport services and the largest gaps are related to "security" and "busload" constructs.

Finally, referent to variability of the expectations and perceptions values we can conclude that to expectations the values present moderate variability. However, to perceptions, the values denote high variability. It means that the perceptions are more heterogeneous than expectations, considering the results obtained from this research.

References

Ancarani, A., & Capaldo, G. (2001). Management of standardised public services: A comprehensive approach to quality assessment. *Managing Service Quality, 11*(5), 331–341.

Brown, S. W., & Bitner, M. J. (2007). Mandating a service revolution for marketing. In R. F. Lusch & S. L. Vargo (Eds.), *The service-dominant logic of marketing: Dialog, debate and directions*. Armonk, NY: M.E. Sharpe.

do Amaral, A. M., Muniz, J. A., & de Souza, M. (2007). Avaliação do coeficiente de variação como medida da precisão na experimentação com citros. Available: www.webnotes.sct.embrapa.br/pab/pab.nsf/…/$FILE/pAB04796.doc, March 23, 2014.

Everett, P., & Watson, B. (1987). Psychological contributions to transportation. In D. Stokols & I. Altoman (Eds.), *Handbook of environmental psychology* (Vol. 2, pp. 987–1007). Malabar, FL: Krieger Publications.

Friman, M., Edvardsson, B., & Gärling, T. (2001). Frequency of negative critical incidents and satisfaction with public transport services (I). *Journal of Retailing and Consumer Services, 8*(2), 95–104.

Gebauer, H., Hohnson, M., & Enquist, B. (2010). Value co-creation as a determinant of success in public transport services—A study of the Swiss Federal Railway operator (SBB). *Managing Service Quality, 20*(6), 511–530.

Grönroos, C. (1984). A service quality model and its marketing implications. *European Journal of Marketing, 18*(4), 36–44.

Malhotra, N. K. (2001). *Pesquisa de mercado: uma orientação aplicada. Trad. de Nivaldo Montingelli Jr. e Alfredo Alves de Farias* (3rd ed.). Porto Alegre: Bookman.

Pantouvakis, A. (2010). The relative importance of service features in explaining customer satisfaction: A comparison of measurement models. *Managing Service Quality, 20*(4), 366–387.

Parasuraman, A., Zeithaml, V. A., & Berry, L. L. (1985). A conceptual model of service quality and its implications for future research. *Journal of Marketing, 49,* 41–50.

Pérez, M. S., Abad, J. C. G., Carrillo, G. M. M., & Fernández, R. S. (2007). Effects of service quality dimensions on behavioural purchase intentions—A study in public-sector transport. *Managing Service Quality, 17*(2), 134–151.

Pimentel, G. F. (2000). *Curso de Estatística Experimental* (14th ed., 477 p). Piracicaba: Degaspari.

Shimakura, S. (2011). Bioestatística. Available: http://leg.ufpr.br/~shimakur/CE055/ce055.html, March 25, 2014.

Soares, J. C. V., Dias, G. V. S., Souza, M. A., Silva, V. A. G., & Lima, N. C. R. (2016). Desenvolvimento de uma escala de avaliação de serviços de transporte público: resultados preliminares. In *IV Encontro do Centro-Oeste Brasileiro de Engenharia de Produção—ENCOBEP 2016*.

Tse, D. K., & Wilton, P. C. (1988). Models of consumer satisfaction formation: An extension. *Journal of Marketing Research, 25,* 204–212.

A Model and a Methodology for the Systematization of Continuous Improvement of Logistics Processes in World-Class Companies

P. Afonso and E. Fertuzinhos

Abstract Currently, it is fundamental for world-class organizations to implement effective continuous improvement processes which ask for significant and sustainable cost reduction programs. However, there is a lack of models and methodologies that support and validate continuous improvement in organizations. Its application in the logistics operation is particularly important because, currently, it is a determining factor of competiveness and differentiation, affecting significantly the profitability of organizations. In this investigation, an innovative model of continuous improvement based on costs has been developed and implemented; it is structured on three main steps: (1) a definition of cost management responsibilities, (2) establishing a relationship between financial performance indicators and operational indicators and (3) a dynamic generation of a continuous cycle of continuous improvement. Its implementation results also in a three level maturity model (A–C). The model was developed and implemented in a benchmark logistics department of one of the most important first tier suppliers of the automotive industry. The studied company made possible the implementation of the model in its fullness (level C), since the logistics department is in a high maturity level of the cost management and performance measurement process. This model can be replicated in other companies, departments and supply chains that want to reduce the costs proactively through really effective and efficient continuous improvement processes.

Keywords Performance measurement · Continuous improvement
Key performance indicators · Logistics costs · Cutting-costs

P. Afonso (✉)
Production and Systems Department, School of Engineering, University of Minho, Campus de Azurém, 4800-058 Guimarães, Portugal
e-mail: psafonso@dps.uminho.pt

E. Fertuzinhos
Bosch Car Multimedia Portugal, Rua Max Grundig, 35, Braga, Portugal
e-mail: Eurico.Fertuzinhos@pt.bosch.com

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1 Introduction

In order to address the inefficiencies of control systems as a tool to support performance analysis, further integration of financial measures and operational measures is necessary. However, there is still a weak link between the financial and operational areas despite the broad consensus of a view that integrates financial measures with operational measures (Kaplan and Norton 1992). The difficulties go beyond the disconnection of operational and financial metrics. Indeed, the trigger that forces performance gains and continuous improvement comes usually from an external source, for example, the quotation of a product being too high or the cost of an important input to have risen dramatically.

Nowadays, it is important for organizations to be proactive and understand the state of its process of production and business, at any moment and under different perspectives; allowing the construction and implementation of effective and efficient continuous improvement processes. However, there is a lack of models and methodologies that adequately support continuous improvement in organizations. Existing performance measurement models are, in rule, based on the past best practices, that is, practices that organizations have been experiencing. Thus, organizations can't predict the impact of decisions they make, do not compare the actual impact with what would be expected, and have no way of validating decisions.

This research project focused on the development of a model to support the systematization of continuous improvement in the manufacturing industry. The developed model was implemented in a plant of Bosch Car Multimedia, in the Logistics department. The studied company made possible the implementation of the model in its fullness, since it is in a high maturity level of cost management and performance measurement.

Logistics is an important process in modern companies, currently considered by many companies as a determining factor of competiveness and differentiation, affecting significantly the profitability of the organization. Logistics costs are today one of the main economic indicators of the efficiency of world-class companies particularly for those which the supply chain is an important element of the business, due to the increasing distances, different currencies and cultures that separate customers, suppliers, manufacturers and buyers, among other aspects (Zeng and Rosseti 2003).

The general objective of this work was to develop, implement and validate a model that allows to establish a relationship (logistics) costs and performance indicators, allowing a better identification of the resources that can be considered in cost reduction initiatives towards a continuous improvement perspective.

2 Performance Measurement and Metrics

In a performance management system we should, first, define the objectives which will ask for adequate measures and subsequently planning, communication, monitoring, reporting and feedback activities. These systems are embedded in the most important enterprise resource planning systems, as for example SAP, Oracle, etc. Typically, its operationalization is done by monitoring and measuring the performance of key performance indicators (KPI) (Cai et al. 2009). Bourne et al. (2003) emphasize that: (1) performance measurement is multidimensional by including financial and non-financial measures, as well as internal and external measures; (2) performance measurement cannot be taken in isolation: both efficiency and effectiveness of the action need to be analyzed and performance measures must be developed from the wider perspective of the strategy of the organization; (3) performance measurement has influence on the employees and on the organization as a whole.

Furthermore, Meyer (2002) defines seven purposes of measuring performance at different levels of the organization. Performance measurement allows evaluating the results of past activities and preparing future performance. Improving the performance of organizations depends to a large extent on the contribution of the ordinary employees, who must be properly motivated and receive adequate financial and non-financial compensation. In large companies, measures are expected to bottom up and then replicate or spread to other business units in a top–down process. Finally, a performance measurement system allows to compare departments, business units and companies going much further than initial objectives typically suggest.

For Parmenter (2007) the indicators can be divided into four types: (1) Key Result Indicators (KRI)—convey what the organization achieved in terms of its critical success factors; (2) Result Indicators (RI)—show what organization did; (3) Performance Indicators (PI)—indicate what organization should do; (4) Key Performance Indicators (KPI)—highlight what the organization has to do to significantly increase its performance.

3 Methodology and Case Study

Since it was intended to develop and a model and a methodology for the systematization of continuous improvement, action research seemed to be an appropriate methodology because it supports situations in which the researcher is engaged and actively participates in solving a problem, or fulfils a need to create new and relevant solutions for both the academy and the companies (Saunders et al. 2009). This research method emphasizes a natural interaction of a process compounded of diagnosis, planning, action and a spiral evaluation, inserted in a specific context and with a clear purpose.

This project has been divided into several stages. The first phase took about a month and a half and essentially consisted of designing the model. The next stage focused on the analysis of the status quo of performance measurement in the logistics department and on the activities carried out at the level of cost control as well as its relation with the performance indicators. The duration of this analysis was approximately one month. The implementation of the template was then performed, as well as the creation of a dashboard to support it. In the next moment, the trees of performance indicators were created that allow to relate the operation with the correspondent costs. Finally, the implementation of a systematized process for continuous improvement was implemented and the validation and impact of the proposed model and methodology were analysed. This phase consumed about three months.

The research project was developed in the Logistics department of Bosch Car Multimedia in Braga which is a company's worldwide benchmark plant. Currently, this plant employs more than 2500 employees and turnover exceeds 600 million euros, with an expected significant growth in the coming years. The logistics department has approximately 260 people and manages a budget of approximately 20 million euros. The structure of the department is adjusted to "Source, Make and Delivery", with areas to support the operation.

This department has taken a big step towards improving its overall performance by creating the controlling section in 2009 which is responsible for managing and reducing costs, performance measurement and continuous improvement. But in 2009 and 2010, logistics costs continued to be communicated and monitored solely and exclusively by the finance department and reports were submitted annually without any detection or alert for any deviation. In 2011, there were very basic reports where it could be obtained very general information about logistics costs, such as: fixed and variable costs and within these: personnel costs, inbound and outbound freight costs, etc. In 2012, there was an improvement in the quality of cost control with the creation of the Cockpit Chart for the two main sources of logistics costs: freight costs and personnel costs. Freight and staff costs in 2012 accounted for approximately 61% of total costs. At that moment, these Cockpit Charts and one more for the control of scrap, contributed to savings of two million euros compared to the previous year. In the following year, 2013, it was possible to obtain more detailed reports from the financial department and by this time the information was already updated monthly which allowed a great advance in the detection of deviations and, with this, in the identification of opportunities for continuous improvement. In 2014, the information, already consolidated and updated monthly, allowed to begin to connect the operational KPI to the corresponding costs in the existing cost structure. At that time a reporting tool was created, based on SAP allowing the production of reports by cost centre or cost account, called WILCO—Worldwide Logistics Costs, which allowed greater independence and transparency in the relationship of the Logistics department with its own (logistics) costs.

Even with all this track record and cost-cutting work, continuous improvement has never really been implemented, with the need for cost reduction being externally driven by both clients and more demanding budgets from the company's headquarters. However, the department's current maturity allowed the implementation of the level C of the model developed in this research level, i.e. the highest level of maturity of the cost management model, explained in the following section.

4 Results and Discussion

Over the years, the Logistics department of Bosch Car Multimedia in Braga has been able to find opportunities to reduce costs. However, the optimization of the activities that came naturally from such process and a significant reduction of the budget in 2016 put the challenge of reducing costs to a new level, creating difficulties and asking for the ability to anticipate in a continuous basis the budget requirements through a policy of proactive identification of cost reduction opportunities. Among the main difficulties identified were the following: limited understanding of responsibilities/intervention on costs and the capacity to define the trigger that increases operational performance or reduce costs in each particular operation, activity or project.

Therefore, the implementation of this model proved to be important helping the Logistics department to adopt a proactive instead of reactive attitude for performance measurement and continuous improvement.

It was agreed to maintain the seven main logistics activities identified by the company's headquarters as a basis for the tool developed for the implementation of the model which are: (1) capital charges, (2) freight costs, (3) packaging costs, (4) logistics personnel costs, (5) other external Logistics-service costs, (6) customs and (7) scrap, depreciation and other logistics related costs.

In Fig. 1 we can see a description of the respective activities and sub activities as well as the costs attributed at a given time of the year. After processing this information the next step is its incorporation into the dashboard.

The proposed dashboard allows controlling the costs and evaluating the performance of the Logistics department in different ways (comparing actual and budget, current with correspondent in the past period, current versus target, according to cost structure, in absolute or relative value, in percentage of total net sales, etc.). Figure 2 shows an example of the Dashboard, in this case with information on the costs accumulated till September 2016.

It should be noted that the green colour shows a better performance comparing current with the selected for comparison, red indicates worse performance. In the continuous improvement monthly meetings the situations indicated by the bars in red are the most discussed. In this discussion, the controlling section and those responsible for the flagged costs present and discuss the causes for deviations. In this analysis, not all points result in an improvement activity or project, because sometimes the bad results are explained by wrong postings, anomalous situations duly explained or result from a sporadic spending that is not going to repeat itself.

Capital Charge	Capital charge EZRS Capital charge EZ
Freight Costs	Freight costs inbound Freight costs inbound special Freight costs outbound Freight costs outbound special
Packaging Costs	Packaging Material Inbound Packaging Material Outbound
Logistic relevant personnel costs	PPC Fix PPC Var SG&A Fix SG&A Var
Other external logistics-service costs	LSP Other Costs
Customs	Customs duty - goods inc Customs duty - goods out
Scrap, Deprec., other log. rel. costs	Scrap / discard stock & WIP Other overhead costs

Fig. 1 The 7 logistics activities and sub activities and corresponding costs (hidden)

Fig. 2 Screenshot of the dashboard (costs are hidden)

Fig. 3 Continuous improvement cycle of the model

Thus, the cycle of continuous improvement that underlines the model designed passes in the first moment by analyzing the data and identifying cost deviations and opportunities, and secondly by the definition of tasks, activities or projects, in order to fill the gaps or to take advantage of opportunities identified in the first moment. Then, the impact of the previously identified measures is forecasted, using both financial and operational measures, followed by the implementation in a fourth moment, after the validation of the impacts by the controlling. In a fifth moment, after the implementation, the real achieved versus the expected will be compared. This moment is central to the perceived effectiveness and real efficiency of the measures. And the cycle completes allowing itself to start over again and again (see Fig. 3).

This model can be applied to any type of industry regardless of its size, age or degree of maturity of the business processes. However, there are conditions to be taken into account in order to ensure that the model can be fully implemented and for this purpose three levels of organizational maturity can be considered named here as A, B and C.

- Level A requires the existence of a cost structure (matrix) where cost types or accounts and responsibility centres are. A structured cost allocation and measurement and a clear definition of the responsibilities are a fundamental basis for understating, managing and reducing costs.
- Level B requires the definition of objectives, e.g. based on the general budget or forecasts, for each "coordinate" activity × responsibility centre of the structure previously defined in level A; also asks for the construction of a KPI matrix for each "coordinate" and setting targets for their respective KPI; indicator trees should relate operational indicators to financial indicators.

- Level C allows the implementation of the continuous improvement cycle described above. With the two previous levels satisfied, the identification of deviations or opportunities for improvement is enhanced and transparent to the organization. Thus, a continuous improvement process can be implemented.

5 Conclusions

In this investigation, an innovative model of continuous cost improvement has been developed and implemented, based on a clear definition of cost management responsibility, the relationship between financial performance indicators and operational indicators and, finally, a continuous improvement cycle. The studied company made possible the implementation of the model in its fullness, since it is in a high maturity level of the cost management process. The developed and validated model in this investigation allows a better visualization and transparency of the logistics operation process, clarifies the contribution of different sections for costs, supports a methodology that monitors, define measures/projects to correct deviations and validate the actual versus estimated impact of the implemented measures; this way, allows to establish a relation between the operational performance, the costs and the results of the company. This model can be replicated in other companies, departments and supply chains that want to reduce the costs proactively through really effective and efficient continuous improvement processes.

References

Bourne, M., Neely, A., Mills, J., & Platts, K. (2003). Implementing performance measurement systems: A literature review. *International Journal Business Performance Management, 5*(1), 1–24.

Cai, J., Liu, X., Xiao, Z., & Liu, J. (2009). Improving supply chain performance management: A systematic approach to analyzing iterative KPI accomplishment. *Decision Support Systems, 46,* 512–521.

Kaplan, R., & Norton, D. (1992). The balanced scorecard—Measures that drive performance. *Harvard Business Review*, 72–79.

Meyer, M. (2002). *Rethinking performance measurement: Beyond the balanced scorecard*. New York: Cambridge University Press.

Parmenter, D. (2007). *Key Performance Indicators (KPI): Developing, implementing, and using winning KPIs*.

Saunders, M., Lewis, P., & Tornhill, A. (2009). *Research methods for business students* (5ª ed.). Essex: Pearson Education Limited.

Zeng, A., & Rosseti, C. (2003). Developing a framework for evaluating the logistics costs in global sourcing process. *International Journal of Physical Distribution & Logistics Management*, 785–803.

Part II
OR, Modelling and Simulation

Mapping the Perception of Users as the Usability of Smartphones: Benchmarking Features Through the Borda Count Method

M. Santos, T. Silva, C. Gomes, J. Vieira and R. Walker

Abstract Smartphone devices are one of the products most bought by consumers and show the differential of the device in the sale may not be the only positive point, but it is also necessary to be able to keep the device being intuitive in its functions over time, in order to retain the consumer to the brand. Currently both the software and the hardware of the devices are becoming more equal, as both market companies are using the same manufacturers in their products. In this trend, usability is a factor that will contribute to customer satisfaction. For businesses, access to information on which functions are most used and what deserve more prominence is essential to create new interfaces of the operational system. For that, it was used the Borda's method of operational research to rank in a compensatory way those functionalities.

Keywords Borda method · Smartphones · Operational system
Operational research

M. Santos (✉)
Department of Systems Engineering, Brazilian Navy, Centro de Análises de Sistemas Navais, Ilha das Cobras, Rua da Ponte, edificio 23, Centro, RJ 20091-000, Brazil
e-mail: marcosdossantos_doutorado_uff@yahoo.com.br

T. Silva
Department of Industrial Engineering, SENAI CETIQT University, Rua Magalhães Castro 174, Riachuelo, RJ 20961-020, Brazil
e-mail: thi.l.porto@hotmail.com

C. Gomes · J. Vieira · R. Walker
Department of Industrial Engineering, Federal Fluminense University, Rua Passos da Pátria 156, São Domingos, Niterói, RJ 24220-240, Brazil
e-mail: cfsg1@bol.com.br

J. Vieira
e-mail: josearturmv@gmail.com

R. Walker
e-mail: rubens.walker@gmail.com

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1 Introduction

Over time, not only businesses have seen the need for dynamic and globalized communication, but individuals have begun to use their personal computer with a focus on search, shopping, social media use, and so on. This ended up popularizing the use and having an increase in the number of people with access to the internet (IBGE 2015).

Currently, the market has several devices acting with the objective of facilitating various services using the internet through websites, applications or interfaces. According to a survey carried out in 2015 by the IBGE called National Survey by sample of households (PNAD), which aims to produce basic information for the study of the socioeconomic development of the country, the two main ways to access it are computer and cell phone, taking a greater focus on the last mentioned, because in recent years there has been an increase in the number of uses that have made it the most used device for navigation in Brazilian households.

Sales of the Smartphone is very large in the world. In 2015, 1.5 billion mobile phones were shipped to stores. This total is 11.9% higher than in the previous year (IDC 2015). IDC Brasil affirms that in the Brazilian market in 2014, 104 smartphones were sold per minute, making Brazil the fourth country with the largest number of sales in the world, behind only the United States, India and China.

Smartphones are now so capable of complex tasks. Steve Jobs when he announced the first iPhone, introduced him as a pocket computer (T3 2016) due to the ability of this device to solve various tasks.

According to Nielsen and Loranger (2007) in the 19th century, browsing the internet was very different from today, because today it is part of the routine of people, and is now considered a tool. With the increasing number of new sites, the ease of use and understanding began to be focus in this same century. And it has been identified that if this instrument is easy to understand it will be used, otherwise it will not. Winckler and Pimenta (2016) discussed how, over time, several sites started to be created, and problems with the interaction started to occur, because users entered more than once on the sites not for interest but because they can’t find the desired information.

Krug (2010) believes that users do not want to think about the moment of using the software. Any application or site that has functions that are more than two clicks away or is not easily understood is considered a problem. Fact that he considers as the first law of usability.

Usability is a study related to ergonomics and human-computer interaction (IHC), that is, these two fields of learning form the study on the usability of products and interactive environments. Ergonomics is internationally defined as “… a discipline that deals with understanding the interactions between humans and other elements of a system …” (ABERGO 2002). And the IHC is a discipline that aims to improve the design, implementation and evaluation of all types of computer systems that have human interaction Hewett (1992) apud. Barbosa and Silva (2010).

Several companies are involved in the creation, development and assembly of smart mobile devices. In a broad market such as this, a small change may end up becoming the brand's differential. Therefore, increases in hardware and software are realized, both in the operating system and in the diffusion of new technologies in equipment. However, in most cases both companies put in their devices the best of what is on the market offered by hardware manufacturers partners, thus possessing devices that only differ in logo and design.

The study of the interaction of users with the smartphone can be a criterion of choice for the customer and even a competitive differential in this market. Therefore, this work aims to help smartphone manufacturers to identify potential points of improvement in the access of functions in their operating systems and thus acquire a differential in this market.

2 Problem

The ease of understanding when using a device is important and the consumer's head is critical. With every passing day, users expect not only innovations and novelty in the Smartphone market, but also in interaction with Smartphones, mainly because they use this device for several functions on a daily basis.

The mobile operating system market is extremely restricted to 3 major brands, and it is up to them to compete for almost the entire market. Android, created by Google in 2008 is used by most manufacturers today, iOS, created by Apple in 2007 is used exclusively on Smartphone's iPhones and Windows Phone, created by Microsoft in 2010 is used by few companies other than Microsoft itself (SMART WORLD 2013).

According to IDC in 2016 the companies that sold the most worldwide were Samsung (22.8%), Apple (11.7%) and Huawei (9.3%).

In Brazil, the company that most sells smartphone devices is Samsung, as can be seen in Fig. 1, which shows the Market Share in percentage.

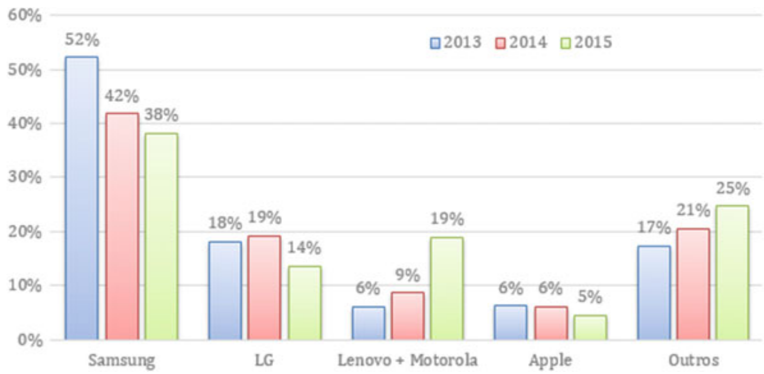

Fig. 1 Market Share: comparison of sales of smartphones devices in Brazil. *Source* Olhar Digital (2015)

To attract more consumers, manufacturers produce updates to their operating systems throughout the year, introducing new functions and even changes to improve the usability of the device, thus facilitating interaction between users and the smartphone. Therefore, the lack of innovation in functions and functionalities or problems related to interaction can impact on customer satisfaction.

Thus, this research aims to answer the following question: What features should be a focus on usability improvement in view of the daily use of consumers?

3 Objective

This work aims to identify and rank, using the Borda's method, the functions that are most used in the everyday of users so that they are the target of improvements in usability in operational systems of smartphone devices. Two field surveys were carried out, the first one aiming to discover, among the main functionalities listed, which would be the seven that are most used in the day to day of the researched ones and the second one with the objective of ranking the seven functionalities most used.

For this study, the Magical Number Seven (Miller 1955) method of choice was used, in which he identified that the adult memory capacity was seven elements with a variation of two, regardless of whether the elements were words, digits, symbols or others. This method was used in the second survey to avoid that a very large number of rankings would confuse the respondents. The second method used was the Borda's method, to identify in a compensatory way, which functionality among the seven is most used on a day to day basis.

The first survey was sent on October 3, 2016 and was online and available for access until October 10, 2016, with 82 responses being received. The second survey was conducted on October 17, 2016 and remained online until October 18, 2016. It obtained a total of 21 responses.

4 Methodology

dos Santos et al. (2016) affirm that the use of OR is justified by the fact that it is a science composed of innumerable techniques and models intrinsically related to the optimization of productive systems, that is, to produce more and better from a given Quantity of inputs. Therefore, OR is an optimization tool par excellence.

The Operational Research operates in 5 large areas that are interrelated, as shown in Fig. 2.

Santos et al. (2015) affirm that Operational Research uses mathematical and/or logical models to solve real problems, presenting an eminently multidisciplinary character. Therefore, Santos (2013) also states that according to the type and complexity of the problem to be studied, the best models will be chosen to adhere to that reality.

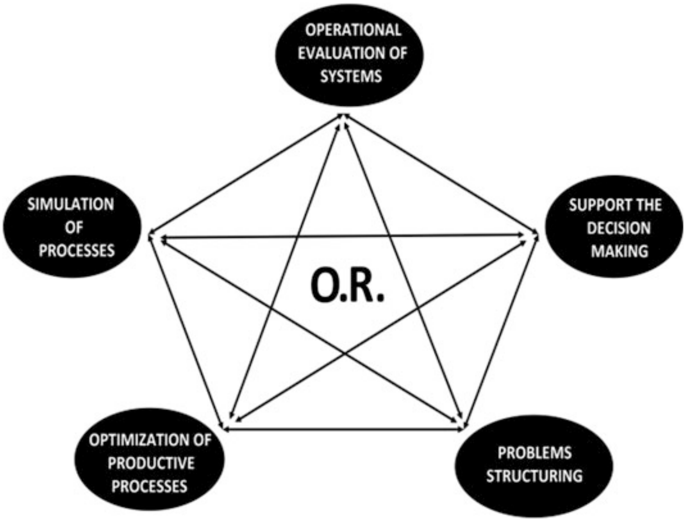

Fig. 2 Areas of operation of the OR. *Source* Prepared by dos Santos et al. (2016)

5 Conclusion

This method was proposed by Jean-Charles de Borda in 1781, as a procedure to aggregate the judgment of several members of a Jury (Borda 1781; Nurmi 1983). The basic idea is adapted by the multicriteria decision, considering each criterion as one of the members of the jury. There are some variants for this method. The simplest of these variants is given below.

It is a weighted position method, which has an axiomatic structure (Nurmi 1983). The method consists in ordering all the alternatives for each criterion, assigning k_1 points to the first, k_2 points to the second, and so on. Considering m changes in the set A, we have k_j, which is called the Borda's coefficient, so that $k_1 > k_2 > k_3 > \cdots > k_m \geq 0$.

The aggregation consists of the sum of the points that each alternative obtains for each criterion. So the first alternative of the ranking, called "Borda's Winner", is the one with the highest number of points, and so on, to the last alternative, with fewer points.

Initially the alternatives are ordered for each criterion i, according to a complete pre-order. The alternative j receives the ranking $r_i(a_j)$ according to criterion i. Thus, $r_i(a_j)$ will be the function associating k_j with a_j. Then we have: $r_i(a_j) = k_1$, $r_i(a_2) = k_2$, $r_i(a_3) = k_3$, $r_i(a_4) = k_4$ etc.

For the determination of the Borda's coefficient, we can adopt the following parameterization: consider the worst alternative $k_m = $ a, and, for the next alternative (second worst), the value a + b, for the next (third worst), value a + 2b, and so on. Generally, a = 0 and b = 1.

To perform the aggregation of the criteria we have the function b(a_j), obtained as follows:

$$b(a_j) = \sum_{i=1}^{n} r_i(a_j) \tag{1}$$

After analyzing the survey responses, it can be verified that the seven main functionalities identified as most used were the Wi-Fi functions (On/Off/Configure), Alarm clock, Internet browser, E-mail, Camera, 3G/4G data (On/Off) and Smartphone Sound (Up/Down/Off/Vibration). In total numbers we have Table 1.

After the functions were listed, they were ordered using the Borda's method, which is an ordinal multi-criterion evaluation method that will serve to evaluate the alternatives that best fit the defined criteria (Kansas et al. 2006 apud Silva 2015). Adding all the settings indicated by the respondents to each feature will get a number for each feature. The feature that gets the lowest total amount will be the best placed placement (Table 2).

Table 1 Seven functionalities most voted

Functionality	Total quantities
Wi-Fi (on/off/configure)	69
Alarm clock	59
Internet browser	54
E-mail	51
Camera	49
3G/4G data (On/Off)	35
Smartphone sound	34

Table 2 Score of Borda's method

Functionality	1	2	3	4	5	6	7	Total
Internet browser	4	3	4	6	3	0	1	68
Wifi	4	5	2	3	1	4	2	75
3G/4G data	5	2	2	4	1	6	1	79
Alarm clock	4	4	2	1	4	2	4	82
E-mail	2	4	4	2	3	3	3	84
Camera	0	2	4	4	6	2	3	95
Smartphone sound	2	1	3	1	3	4	7	105

6 Final Consideration

It was identified by the Borda method that Internet browsing would be the main functionality that should be focused to improve usability with the operating system of the device. Although the Wi-Fi feature has been the most chosen, the method chosen to use in this work is compensatory in nature, the high performance in one placement can compensate for another.

Although it is easy to identify that all seven functionalities deserve improvement studies in usability, it should prioritize the functionalities in the order listed by the Borda's method, that is, the first function that must be improved for its device be highlighted in usability in the user's perception is the internet browser.

With the disuse of the computer and the notebook, because the smartphone is increasingly accumulating tasks that were carried out by other equipment, the internet browser, a function little explored by the operating system because it has always been considered secondary in a smartphone, ends up becoming a target improvement.

References

Barbosa, S. D. J., & Silva, B. S. D. (2010). *Interação Humano-Computador* (1st ed.). Rio de Janeiro: Editora Campus—Elsevier.

Borda, J. C. (1781). *Mémoire sur les elections au scrutiny*. Paris: Histoire de l'Académie Royale des Sciences.

de Jannuzzi, P. M., Miranda, W. L., & Silva, D. S. G. (2009). Análise Multicritério e Tomada de Decisão em Políticas Públicas: Aspectos Metodológicos, Aplicativo Operacional e Aplicações. *Informática Pública, 11*(1), 69–87.

dos Santos, M., et al. (2016). Proposta de otimização do mix de produção utilizando o Método Simplex: um estudo de caso de uma confecção de moda íntima do município de Cordeiro – RJ. In: Anais do IV Simpósio de Engenharia de Produção: Lean Cost Management como filosofia global de otimização em organizações. Recife (PE): FBV.

Eisenhart, K. M., & Zbaracki, M. J. (1992). Strategic decision making. *Strategic Management Journal, 13*, 17–37.

Hillier, F. S., & Lieberman, G. J. (2012). *Introdução à pesquisa operacional* (9th ed.). Porto Alegre: Editora AMGH.

IBGE. (2015). Pesquisa Nacional por Amostra de Domicílios (PNAD) 2015. Disponível em: http://www.ibge.gov.br. Acesso em: 2016.

IDC. (2015). Worldwide Smartphone 2015–2019 forecast and analysis. Disponível em: http://www.idc.com/getdoc.jsp?containerId=254912. Acesso em: 2016.

IDC. (2016). Smartphone Vendor Market Share, 2016 Q2. Disponível em: http://www.idc.com/prodserv/smartphone-market-share.jsp. Acesso em: 2016.

Janis, I. L. (1989). *Crucial decissions*. NY: Free Press.

Krug, S. (2010). Simplificando coisas que parecem complicadas. 1º Edição. Altas Book, Rio de Janeiro.

Miller, G. A. (1955). The magical number seven, plus or minus two some limits on our capacity for processing information. *Psychological Review, 101*(2), 343–352.

Neto, M., & José, O. (2013). Usabilidade da interface de dispositivos móveis: heurísticas para o design. 2013. 118 f. Dissertação (Mestrado em Ciências de computação e matemática computacional) – Instituto de Ciências Matemáticas e de computação, Universidade de São Paulo.

Nielsen, J., & Loranger, H. (2007). (1st ed.). Rio de Janeiro: Editora Campos—Elsevier.

Nurmi, H. (1983). Voting procedures: A summary analysis. *British Journal of Political Science, 13*(2), 181–208.

Pomerol, J., & Barba-Romero, S. *Multicriterion decision in management: Principles and practice* (1st ed.).

Rezende, P. L. (2007). *Hardware—Placa Mãe*. Minas Gerais: SENAI.

Santos, M. (2013). Simulação da Operação de um Sistema Integrado de Informações para o atendimento pré-hospitalar de emergência no município do Rio de Janeiro. Dissertação de M. Sc., COPPE/UFRJ, Rio de Janeiro, Brasil.

Santos, M., et al. (2015). Simulation of operation of an integrated information for emergency pre-hospital care in Rio de Janeiro Municipality. *Procedia Computer Science, 55*, 931–938. https://doi.org/10.1016/j.procs.2015.07.111.

Silva, E. J. C. (2015). Aplicação do método de borda para avaliar as decisões coletivas: Um estudo sobre a avaliação de processos críticos afetados pela estratégia de uma empresa do setor elétrico. ENEGEP 2015, Fortaleza, CE, Brasil, 13 a 16 de out. de 2015.

Simon, H. (1997). *Administração behavior* (4ª ed.). New York: The Free Press.

Smart Mundo. (2016). Sistemas operacionais que existem hoje para Smartphones. Disponível em: http://smartmundo.com/sistemas-operacionais-para-smartphones/. Acesso em: 2016.

T3. (2016). A brief history of the iPhone. Disponível em: <http://www.t3.com/features/a-brief-history-of-the-iphone>. Acesso em: 2016.

Winckler, M., & Pimenta, M. S. (2016). Avaliação de usabilidade de sites web. Disponível em: https://www.irit.fr/~Marco.Winckler/2002-winckler-pimenta-ERI-2002-cap3.pdf. Acesso em: 2016.

Economic Complexity and Quality of Life in Latin America and Asia Between 2010 and 2014

D. Ferraz, H. Morales, J. Campoli and D. Rebelatto

Abstract The objective of this article is to measure the efficiency of the Latin American and Asian countries in converting economic complexity into quality of life between 2010 and 2014. The method used was Data Envelopment Analysis (DEA). The results showed in 2014, all Asian countries were efficient except China and Philippines. Cuba was the country that most served as benchmark for inefficient countries. The window analysis showed only Japan, South Korea and Singapore remained effective over time.

Keywords Data envelopment analysis (DEA) · Economic complexity
Human development · Latin America · Asia

1 Introduction

Economic growth does not fully explain human development. Goods that a country is able to produce depends on available knowledge, which is reflected in jobs and economic diversification. In addition to growth, is essential creating conditions for innovation, competitiveness and economic diversification, which makes a country more complex.

D. Ferraz (✉) · J. Campoli · D. Rebelatto
Department of Industrial Engineering, University of Sao Paulo (USP),
São Paulo, Brazil
e-mail: diogoferraz@usp.br

J. Campoli
e-mail: jessica.campoli@usp.br

D. Rebelatto
e-mail: daisy@sc.usp.br

H. Morales
Department of Industrial Engineering, Federal University of São Carlos (UFSCar),
São Paulo, Brazil
e-mail: herickmoralles@dep.ufscar.br

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The complexity of a country stems from type of goods produced, which is reflected in its productive structure. Countries capable of generating high-tech goods, such as medical equipment, are considered more complex than those that produce raw materials, for example sugar or wood (Hausmann et al. 2014, p. 18).

The economic complexity of a country's has been positively correlated with economic growth. Hidalgo and Hausmann (2009) have shown economic diversification towards technology-intensive sectors leads a country to economic growth and income enhancing in long terms.

Hartmann (2014, p. 84) argues that economic complexity is also related to human development. The author has shown the economic complexity corroborates for people to better develop their "capacities" (education, health, access to infrastructure). A complex country creates new sectors and provides better quality jobs.

This article argues that proving the relationship between economic complexity and human development is not enough. It is necessary to measure the efficiency of countries in converting complexity into quality of life. This is because the most efficient countries can be taken as an example for development of policies in those that are less efficient or inefficient.

The hypothesis that this article defends is that Asian countries are more efficient than Latin American countries, in converting complexity into human development. The problem to be investigated is to evaluate which countries, among the selected ones, are the most efficient.

In view of what has been exposed, the objective of this article is to measure the efficiency of Latin American and Asian countries in converting economic complexity into quality of life between 2010 and 2014.

2 Economic Complexity

The complexity of an economy is related to types of developed products, due to multiplicity of available knowledge. For an economy to be complex, individuals from different areas (finance, marketing, technology, operations, law, etc.) must interact and combine their knowledge, generating more sophisticated products (Hausmann et al. 2014).

To produce certain goods, people and organizations with knowledge are needed. According to Hidalgo and Hausmann (2009), for production of goods are necessary capacities, such as infrastructure, professional qualification, regulations, among others. Countries that produce high-tech goods need more advanced knowledge than countries that are intensive in production of commodities.

Hausmann et al. (2014) argue that complex economies are the ones that generate a great deal of knowledge through a network of people in order to generate a wide variety of knowledge-intensive products. Economies that are not considered complex are those with a narrow base of productive knowledge and produce a smaller variety of goods, which require less knowledge and less integration among people.

The complexity of a country has been assessed by the Economic Complexity Index (ECI), calculated on the basis from the United Nations (Hidalgo and Hausmann 2009). ECI shows production characteristics of economic system, in view of a country's capabilities. The higher the ECI value, the more complex the analyzed country is.

Given the importance of knowledge in complex societies, recent studies have argued that complexity can lead countries to human development. Hartmann et al. (2015) found a strong correlation between economic complexity, income inequality, education, and GDP growth. More complex countries show higher growth of GDP and years of schooling, as well as a more equal income distribution.

Hartmann et al. (2016) compared income inequality and economic complexity between Latin America and some Asian countries (China, South Korea, Singapore and Malaysia). This study is important because Latin America has enjoyed a boom in commodity prices in recent years, which has led to improvement of social indicators, but it has not been able to diversify the region's exportations guideline for industrialized products.

The results of Hartmann et al. (2016) indicated that, although Latin American economies showed social improvements, there was no economic diversification, which reflected lack of better quality jobs. On the other hand, Asian countries that have invested in human capital and technological innovation have made their economies more complex.

3 Method

The efficiency of a system can be measured from the division between the current value of an indicator of system performance and the maximum value that this indicator reaches (Mariano and Rebelatto 2014). The method used to determine system efficiency is called Data Envelopment Analysis (DEA).

The DEA is a nonparametric method, developed by Charnes et al. (1978) and aims, by the empirical construction of a linear frontier by pairs, to measure the productive efficiency of a set of Decision Making Units (DMU) (Cooper et al. 2007).

From the efficiency of each DMU, a ranking of relative efficiency is generated. According to Cook and Zhu (2014), the efficient frontier expresses the maximum number of outputs that can be produced per unit of inputs, representing the production limit determined by the technology. Efficient DMUs represent a "best practice frontier", serving from analysis for the least efficient.

There are different models that can be used to implement DEA. These models differ according to their assumptions. According to Mariano and Rebelatto (2014) and Mariano et al. (2015) type of returns of scale designates the two main DEA models: CRS (Constant Returns to Scale) and VRS (Variable Returns to Scale). The hypothesis of the VRS model considers that the variation of outputs is not necessarily equiproportional to inputs, being that in the frontier there will be three regions: increasing, in which the outputs grow proportionally more than the inputs; Proportionality; and decreasing, where outputs grow proportionately less than inputs (Cook and Zhu 2014).

For this article, 26 countries were selected for analysis. Among them are all Latin American countries and some Asian countries (Japan, China, South Korea, Philippines, Singapore, Thailand and Malaysia). The selection of these countries is based on previous study by Hartmann et al. (2016). The choice is justified because the Asian countries have improved indicators of quality of life, growth and economic complexity in relation to the countries of Latin America.

We choose the output-oriented DEA-BCC model. The choice of this model is justified because the variable returns to the countries' scale are taken into account. We decided to take the orientation to output, considering that one wants to maximize outputs (quality of life) without reducing input (economic complexity).

We performed a window analysis, used to include the temporal factor in DEA. According to Cooper et al. (2007), this type of analysis separates the analyzed years into distinct groups, called windows. The period between the years 2010 and 2014 was considered, and the size of each window will be 3 and the number of windows will also be 3. We applied the DEA-VRS to each of the windows. The result of the efficiency of each DMU should be average of the efficiencies obtained in all years and in all windows.

The choice of the window analysis is justified because there was a variation in the economic complexity of each country over time, especially for the Latin American countries. Knowing this temporal variation, we argued that the average calculation and standard deviation of the countries' efficiency is more significant to analyze the countries that remained at the efficiency frontier during the proposed period.

3.1 Analysis of Variables

The selection of the variables of this article is based on previous studies, in order to meet the theoretical assumptions from Sen (2001). This paper opts to use as input the Economic Complexity Index (ECI). The ECI is an indicator published annually by the Economic Complexity Observatory. As this indicator has coefficients that can be either positive or negative, it was necessary to proceed with linear normalization.

We choose the following outputs to represent quality of life: (a) longevity, which in this article we used as life expectancy at birth (LE); (b) education, represented by average years of education of the population (AYS); (c) percentage of access to basic sanitation (ABS); (d) employment rate (ER).

The results of correlation matrix show the Economic Complexity Index (ECI), among the analyzed variables, has a higher correlation with life expectancy (0.51). However, average years of education (0.47) and access to basic sanitation (0.42) also showed a good correlation with this index. The only variable that presented the

Table 1 Coefficients, p value and Adjusted R-squared of the outputs in relation to the input

Variable	Coefficient	p value	Adjusted R-squared
AYS	0.38114386	<0.001	0.176340527
LE	0.10338286	<0.001	0.217749074
ABS	0.29721024	<0.001	0.157672421
ER	0.02494116	0.029	0.029113034

lowest correlation was employment rate (0.23), although we could observe a positive correlation, which was expected.

The Correlation analysis showed, a priori, the assumptions made by Hidalgo (2012) and Hartmann (2014) are valid, since more complex societies generate more access to basic sanitation and education, besides guaranteeing greater longevity to the population. In addition to correlation analysis we estimated linear regressions in order to verify the statistical significance and degree of explicability (adjusted R-squared) between the input and each of the outputs (Eq. 1).

$$\log \gamma_{it}^{social\ variable} = \beta_0 + \beta_1 \log \mathrm{ECI}_{it} + \varepsilon_{it} \tag{1}$$

Where: $\log \gamma_{it}$ is one of the variables of quality of life; β_0 is the intercept; $\beta_1 \log \mathrm{ECI}_{it}$ is the Economic Complexity Index. It is proposed to use a log-log regression, since it is possible to interpret the parameters as elasticity (Greene 2011).

Table 1 shows the results found in the linear regression.

Results concerning adjusted R-squared showed the economic complexity explains the variability of indicators of quality of life. The economic complexity (ECI) explained 21.77% of variability of life expectancy (21.77%) for the countries analyzed. Next, the most explained variables were average years of education (17.63%) and access to basic sanitation (15.77%). ECI showed a low degree of explanation for the variability of employment rate (2.9%).

In addition, linear regressions demonstrated statistical significance of ECI for all social variables analyzed. We noted that life expectancy, average years of education and access to basic sanitation were significant at the 1% level. On the other hand, employment rate has shown statistical significance at the level of 5%. Considering statistical significance of the variables, we decided to keep the employment rate as output of the economic complexity.

In summary, the econometric analysis demonstrated that the variables selected for this article are correlated and have statistical significance, which guarantees the relation between input and outputs.

4 Results and Discussion

4.1 Efficiency Estimates for 2014

In 2014, all Asian countries except for China and the Philippines were efficient. In Latin America, Bolivia, Chile, Cuba, Ecuador and Venezuela were efficient. Results indicate that Latin American countries, even with low complexity, can generate good social indicators, which can probably be explained by social policies in the region (Hartmann 2014).

Analysis of benchmarks showed Cuba was the country that most served as reference to inefficient countries. Although Cuba has not been able to diversify its exports, the quality of life indicators was outstanding.

Countries with constant returns are predominantly Latin American (Bolivia, Cuba, Ecuador and Venezuela). This shows these countries are operating at their optimum scale and without waste. Other countries presented a return of decreasing scale, demonstrating the waste of recourses.

Brazil, for example, presented technical efficiency of 95.6%, but the scale efficiency scale was 87.6%. This is because the Brazilian economy has relatively higher economic complexity than the other Latin American countries, but its social indicators were lower than other countries in the region.

4.2 Window Analysis

Between 2010 and 2014, only South Korea, Japan and Singapore were efficient. This result confirms the initial hypothesis of this article that, over the years, Asian countries tend to be more efficient and sustain this efficiency in generating quality of life.

The first Latin American country that appeared in the ranking was Cuba (99.95%), in fifth place. Mariano and Rebelatto (2014) found similar results for a global analysis. According to the authors, countries with socialist past tend to be more efficient in converting wealth into quality of life.

China has worsened its efficiency over time. Although the Chinese economy has become more complex, average years of education, remained static in the last three years of the period analyzed and the employment rate declined.

Table 2 Results of technical efficiency, returns of scale and analysis in window

No.	Country	BCC 2014	Return scale	Window			Mean	Standard deviation
				2010–12	2011–13	2012–14		
1	Singapore	1.000	Decreasing	1.0000	1.0000	1.0000	1.0000	0.0000
2	Korea Rep.	1.000	Decreasing	1.0000	1.0000	1.0000	1.0000	0.0000
3	Japan	1.000	Decreasing	1.0000	1.0000	1.0000	1.0000	0.0000
4	Thailand	1.000	Decreasing	1.0000	1.0000	0.9998	0.9999	0.0002
5	Cuba	1.000	Constant	1.0000	0.9996	0.9990	0.9995	0.0007
6	Chile	1.000	Decreasing	0.9939	0.9978	0.9965	0.9961	0.0043
7	Bolivia	1.000	Constant	0.9925	0.9967	0.9949	0.9947	0.0052
8	Malaysia	1.000	Decreasing	0.9928	0.9935	0.9944	0.9936	0.0029
9	Ecuador	1.000	Constant	0.9840	0.9908	0.9870	0.9873	0.0107
10	Peru	0.988	Decreasing	0.9861	0.9880	0.9858	0.9866	0.0066
11	Guatemala	0.993	Decreasing	0.9819	0.9853	0.9874	0.9849	0.0044
12	Honduras	0.990	Decreasing	0.9807	0.9862	0.9854	0.9841	0.0096
13	Venezuela	1.000	Constant	0.9798	0.9894	0.9821	0.9838	0.0152
14	Paraguay	0.986	Decreasing	0.9755	0.9807	0.9792	0.9784	0.0129
15	Panama	0.982	Decreasing	0.9731	0.9802	0.9807	0.9780	0.0064
16	Nicaragua	0.982	Decreasing	0.9661	0.9846	0.9755	0.9754	0.0242
17	Uruguay	0.980	Decreasing	0.9713	0.9763	0.9714	0.9730	0.0071
18	China	0.971	Decreasing	0.9730	0.9715	0.9706	0.9717	0.0016
19	Argentina	0.975	Decreasing	0.9687	0.9738	0.9687	0.9704	0.0080
20	Costa Rica	0.972	Decreasing	0.9716	0.9715	0.9664	0.9699	0.0052
21	Mexico	0.972	Decreasing	0.9687	0.9689	0.9702	0.9693	0.0013
22	El Salvador	0.959	Decreasing	0.9511	0.9551	0.9558	0.9540	0.0043
23	Brazil	0.956	Decreasing	0.9493	0.9544	0.9543	0.9527	0.0046
24	Philippines	0.948	Decreasing	0.9440	0.9458	0.9456	0.9451	0.0016
25	Colombia	0.928	Decreasing	0.9150	0.9217	0.9237	0.9201	0.0065
26	Dom. Rep.	0.904	Decreasing	0.9050	0.9057	0.9024	0.9044	0.0085

Among the countries with the worst practices, we highlight: Brazil, Colombia Philippines and Dominican Republic. Although Brazil has shown significant improvement over the years, with the complexity that the country has, social variables are still low compared to other countries in this analysis.

Table 2 summarizes the results presented in this article.

5 Conclusion

This article contributed to measuring the efficiency of countries in converting economic complexity into quality of life in the Latin America and Asian countries. We observed the Asian countries are more efficient the ones from Latin America. This result brings an important debate about economic complexity as a way to generate quality of life for the population.

The econometric results showed the need for deepen the analysis of the relationship between indicators of quality of life and the economic complexity. We suggest future studies using other variables besides ECI.

We concluded that industrial policy should prioritize the diversification of the exportations guideline to technologically intensive products. However, the importance of social policies is recognized as generating quality of life in countries with low economic complexity. Therefore, we defend the need for industrial and social policy to complement each other.

References

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision-making units. *European Journal of Operational Research, 2,* 429–444.

Cook, W. D, Zhu, J. (2014). Data envelopment analysis—A handbook on the modeling of internal structures and networks. *International Series in Operations Research & Management Science*. New York: Springer Science + Business Media.

Cooper, W. W., Seiford, L. M., & Tone, K. (2007). *Data envelopment analysis: A comprehensive text with models, applications, references and DEA-Solver Software* (2nd ed.). s.l.: Springer Science Business Media LLC.

Greene, W. H. (2011). *Econometric analysis* (7th ed.). New York: Prentice Hall.

Hartmann, D. (2014). *Economic complexity and human development: How economic diversification and social networks affect human agency and welfare*. New York: Routledge.

Hartmann, D., et al. (2015). *Linking economic complexity, institutions and income inequality*. s.l.: s.n.

Hartmann, D., et al. (2016). The structural constraints of income inequality in Latin America. *Integration & Trade, 40,* 71–85.

Hausmann, R., et al. (2014). *The atlas of economic complexity: Mapping paths to prosperity*. s.l.: MIT Press.

Hidalgo, C. A. (2012). *Discovering East Africa's industrial opportunities*. s.l.: Cornell University Library.

Hidalgo, C. A., & Hausmann, R. (2009). The building blocks of economic complexity. *Proceedings of the National Academy of Sciences, 106*(26), 10570–10575.

Mariano, E. B., & Rebelatto, D. A. (2014). Transformation of wealth produced into quality of life: Analysis of the social efficiency of nation-states with the DEA's triple index approach. *Journal of the Operational Research Society, 65*(1), 1664–1681.

Mariano, E. B., Sobreiro, V. A., & Rebelatto, D. A. (2015). Human development and data envelopment analysis: A structured literature review. *Omega, 54,* 33–49.

Sen, A. (2001). *Development as freedom* (1st ed.). New York: Anchor Books.

The Efficiency of Public Expenditures on Education: Data Envelopment Analysis of Brazilian Federative Units Between 2011 and 2014

J. Campoli, D. Ferraz and D. Rebelatto

Abstract The objective of this article is to determine the relative efficiency of the Brazilian Federative Units in converting public expenditures into improvements in educational indicators between 2011 and 2014. We use Data Envelopment Analysis (DEA) to calculate the efficiency and the Malmquist Productivity Index (MPI) to evaluate the productivity. The efficient Brazilian States in the period were: Alagoas, Amapá, Distrito Federal, Maranhão, Piauí, Rio de Janeiro, Roraima and Amazonas Moreover, the inefficient Federative Units could improve their results by an average of 4.83% in 2011, and 4.87% in 2014, using the same public resources applied.

Keywords Data envelopment analysis (DEA) · Malmquist productivity index (MPI) · Education · Public expenditure

1 Introduction

Education is a fundamental human right, considered essential for exercising of all rights of the individual, for example, the exercise of citizenship and democracy, social and economic inclusion, fight against extreme poverty and generation of income. Despite this, there are some 781 million illiterates and 58 million children out of elementary school worldwide (UNESCO 2016).

According to Sen (2001), when a nation limits access to health and education, it impedes free action of individuals and compromises human development. Therefore, conform the Organization for Economic Co-operation and Development

J. Campoli · D. Ferraz (✉) · D. Rebelatto
Department of Industrial Engineering, University of Sao Paulo (USP), São Paulo, Brazil
e-mail: diogoferraz@usp.br

J. Campoli
e-mail: jessica.campoli@usp.br

D. Rebelatto
e-mail: daisy@sc.usp.br

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—OECD (2016), total public spending on education in Brazil was 16.1% in 2013, being above average of 11.3% of the member countries of OCDE. On the other hand, annual Brazilian expenditure per student in basic education in 2013 was US $3826, while average in OECD countries was US$8477 (OECD 2016).

In this context, quantifying the efficiency of public expenditure is very important because it reveals the inefficiency of decision-making units (DMU) and points to solutions (Kalirajan and Shand 1999; Lovell 2000). To calculate the efficiency we will apply Data Envelopment Analysis (DEA), widely used to measure performance of public expenditures (Afonso et al. 2005; Gupta and Verhoeven 2001).

This article argues about the importance of measuring the efficiency of the 27 Brazilian Federative Units in using public expenditures to improve educational indicators. Therefore, the most efficient Brazilian States can serve as reference for the others, besides pointing out wastes and best practices for allocation of resources.

The hypothesis that this article defends is that not necessarily the Brazilian Federative Units that have more resources are the most efficient. The research problem is to evaluate which Brazilian States are the most efficient. In this way, the objective of this work is to determine the relative efficiency of the Brazilian Federative Units in converting public expenditure in improving educational indicators between 2011 and 2014.

2 Literature Review

Salazar Cuéllar (2014) analyzed the efficiency of public spending in 15 Latin American countries to increase school attendance in the period from 2000 to 2009. The investigation showed inefficient countries could increase primary education by up to 4% and high school by up to 10%, with the same public expenditure applied.

Coco and Lagravinese (2014) considered that some countries are not able to productively use their resources for education due to nepotism or corruption. Relating expenditure on education and the Programme for International Student Assessment (2009) scores, the results showed in developing countries, governance and corruption affect economic performance.

Lavado and Cabanda (2009) measured the efficiency of the Philippine provinces in using investments in education and health in 2008. The efficiency analysis showed the provinces where inequality is higher (Gini Index) presented low efficiency.

Kozuń-Cieślak (2013) studied the efficiency of public expenditures on human capital in Europe. The findings showed no significant differences between the countries analyzed, but it is important to debate about public finance reforms in education and health system.

Dufrechou (2016) analyzed the efficiency of public spending on education in Latin American countries from 1970 to 2010. The increase in efficiency prevailed after 1990 accompanied by the expansion of public expenditures and the increase in income levels are associated with efficiency gains.

In this scenario, through the articles selected, we verified education importance for generating social benefits, observing how a better allocation of public resources can increase social efficiency.

3 Method

Industrial Engineering proposes that in order to analyze a system, it is necessary to determine its inputs and outputs, where Operational Research is the key discipline for development of techniques to measure efficiency (Charnes et al. 1981).

Among these techniques, Data Envelopment Analysis is widely used to calculate efficiency (Vilela 2004). According to Almeida et al. (2006), DEA has a paramount importance, because when measuring efficiency, it aids decision-making.

Defined as a non-parametric method, based on mathematical programming, DEA evaluates the relative efficiency of decision-making units (DMU). The efficiency scale is measured from 0 to 1, when it reaches 1 the analyzed DMU is considered efficient. In this way, a ranking of DMUs is generated, being efficient those ones that can reduce their inputs without decreasing quantity of outputs (Coelli et al. 2005).

Derived from previous studies by Farrell (1957), DEA was first presented by Charnes et al. (1978) with the Constant Returns to Scale (CRS) model. Then, to verify gains in scale in efficiency, Banker et al. (1984) developed the Variable Returns to Scale (VRS) model.

According to Mariano and Rebelatto 2014, several DEA models differentiate by the type of return of scale (increasing, constant or decreasing), their orientation (to input or output) and way of combining variables themselves (inputs and outputs).

In this article, we opted for the Slack Based Model (SBM) model oriented to output and with Variable Scale Returns. Developed by Tone (2001), this model is based on slacks and has already been used in human development analyzes (Põldaru and Roots 2014; Reig-Martínez 2013, 2016). The orientation to output is justified by current Brazilian context, where public spending on education and household income is expected to remain constant and social indicators (outputs) to be maximized.

Besides, we used the Malmquist Productivity Index (MPI), a measure of productivity evolution. Fare et al. (1994) recognized that the distance function implicit in MPI was reciprocal of the technical efficiency measure proposed by Farrell (1957) and then used DEA-based linear programming to develop the DEA-Malmquist and calculate MPI as a measure of productivity.

The technical efficiency (TE) is the result of continuous improvements in production processes, using the same technology. Advances in productivity can also result from technological innovations. Therefore, changes in efficiency can result from using advanced technologies. To estimate the MPI is necessary consider the effect of technology changes (TC) and technical efficiencies (TE) (Ferreira 2009).

To interpret the results of the MPI, TC and TE, we considered as an improvement when the values are greater than 1, and as drawback when the values are smaller than 1. The MPI measures evolution of the ratio between inputs and outputs, TC evolution of technology and TE evolution of relative technical efficiency.

3.1 Analysis of Variables

We selected the variables for this article based on previous studies about the efficiency of public spending on education in Brazil (Delgado and Machado 2007; França and Gonçalves 2015).

We use data from the National Fund for the Development of Education (FNDE 2017a, b and c) and the National Household Sample Survey (PNAD/IBGE 2017).

The period of analysis comprises between 2011 and 2014, due availability of data. In addition, since the beginning of the 2000s, Brazil has undergone social changes, especially with regard to universalization of elementary education, greater access to secondary and higher education, and social changes on income distribution and employment growth (Barros et al. 2006; Cacciamali and Tatei 2016; Hoffmann 2013; Oliveira 2007). Table 1 summarizes the variables selected to this article.

The model inputs present variables related to public spending on education, investment per enrolled student and household average income, which can be directed to students' education.

The outputs are qualitative variables, representing characteristics of population, related to average years of education and school attendance. School attendance is the ratio of the number of students between 15 and 17 years old, who attend school and the total number of people in this age group. We choose this age group because in Brazil average school attendance in secondary school was 82.5% in 2014 (FNDE 2017a, b and c), highlighting a call for improvements in this indicator.

We validated these variables using correlation analysis between inputs and outputs. The variable that most correlates with average years of education was household average income (0.88), followed by investment per student (0.54) and public expenditures in education (0.38). For the variable school attendance, public spending on education (0.44) presented a better correlation than household average

Table 1 Variables selected

Variable	Classification	Source
Total educational revenue	Input	FNDE (2017a, b and c)
Investment per enrolled student	Input	FNDE (2017a, b and c)
Household average income	Input	PNAD/IBGE (2017)
Average years of education	Output	PNAD/IBGE (2017)
School attendance	Output	FNDE (2017a, b and c)

income (0.37) and investment per student (0.13). This analysis demonstrates the correlation of selected variables to use them through DEA.

4 Results and Discussion

We evaluated the Brazilian Federative Units to verify the efficiency in converting public expenditures in education in terms of average years of education and school attendance. We applied the software MATLAB to calculate the efficiency using Data Envelopment Analysis (DEA) and Malmquist Productivity Index (MPI).

DEA results showed the Brazilian States efficient, in 2011, were: Alagoas, Amapá, Distrito Federal, Maranhão, Piauí, Rio de Janeiro, Roraima, Amazonas, Ceará, Pernambuco, Santa Catarina, Paraíba, Mato Grosso, Rondônia and Acre.

The Federative Units remained efficient were: Alagoas, Amapá, Distrito Federal, Maranhão, Piauí, Rio de Janeiro, Roraima and Amazonas. Therefore, the States of Pará, Sergipe and Minas Gerais have become efficient.

However, some Federative Units considered efficient in 2011, became inefficient in 2014: Pernambuco, Santa Catarina, Paraíba, Mato Grosso, Rondônia Acre and Ceará. The MPI elucidates these findings.

The technology changes (TC) explains the most benefited States between 2011 and 2014. The highest TCs were Amapá (AT = 1.03) and Roraima (AT = 1.02). For the Amazon State there was no change (AT = 1).

The Federative Units that obtained higher technical efficiency (TE) values were those that gained more positions. The largest TE was associated to Minas Gerais (1.06), a State that gained 26 positions, moving from 27th place to 1st place. Followed by Rio Grande do Norte stands out (1.03), which went from the 24th position to the 12th place (12 positions). Rio Grande do Sul (1.03) won 7 positions, moving from 25th place to 18th place.

The MPI showed the States that increased the most average years of education and school attendance. The highest MPI was Amapá (1.03) and Roraima (1.02). These states have remained efficient from one period to the next, increasing their outputs. In the case of Amapá, average years of education came from 7.8 to 8.7 and school attendance increased from 82.4 to 85.4% between 2011 and 2014. Therefore, these states have been able to make better use of their income for education.

The efficiency scores also show inefficient Federative Units can improve their results by an average of 4.83% in 2011 and 4.87% in 2014, with the same public expenditure applied. Table 2 summarizes the findings.

Table 2 Efficiency (E), Ranking (R) and Malmquist Productivity Index (MPI) with technology changes (TE) and technical efficiency (TC)

Federative Units	2011		2014		TE	TC	MPI
	E	R	E	R			
Alagoas	1.00	1	1.00	1	1.00	0.96	0.96
Amapá	1.00	1	1.00	1	1.00	1.03	1.03
Distrito Federal	1.00	1	1.00	1	1.00	0.99	0.99
Maranhão	1.00	1	1.00	1	1.00	0.99	0.99
Pará	0.98	17	1.00	1	1.01	0.98	0.99
Piauí	1.00	1	1.00	1	1.00	0.99	0.99
Rio de Janeiro	1.00	1	1.00	1	1.00	0.90	0.90
Roraima	1.00	1	1.00	1	1.00	1.02	1.02
Sergipe	0.94	22	1.00	1	1.02	0.97	0.99
Amazonas	1.00	1	1.00	1	1.00	1.00	1.00
Minas Gerais	0.92	27	1.00	1	1.06	0.95	1.00
Rio Grande do Norte	0.94	24	0.99	12	1.03	0.96	0.98
Ceará	1.00	1	0.98	13	0.99	0.98	0.97
São Paulo	0.97	19	0.98	14	1.01	0.98	0.99
Pernambuco	1.00	1	0.98	15	1.00	0.97	0.97
Santa Catarina	1.00	1	0.98	16	0.98	0.85	0.83
Bahia	0.97	20	0.97	17	1.01	0.98	0.99
Rio Grande do Sul	0.93	25	0.96	18	1.03	0.96	0.98
Paraíba	1.00	1	0.96	19	0.97	0.97	0.94
Tocantins	0.98	16	0.96	20	1.00	0.97	0.97
Mato Grosso	1.00	1	0.95	21	0.95	0.88	0.83
Rondônia	1.00	1	0.95	22	0.96	0.97	0.93
Paraná	0.94	23	0.93	23	1.00	0.93	0.93
Goiás	0.97	18	0.92	24	0.96	0.93	0.89
Espírito Santo	0.95	21	0.92	25	0.98	0.97	0.95
Acre	1.00	1	0.91	26	0.91	0.98	0.89
Mato Grosso do Sul	0.92	26	0.89	27	0.98	0.97	0.95
Average	0.98	–	0.97	–	0.99	0.96	0.96
Max	1.00	–	1.00	–	1.06	1.03	1.03
Min	0.92	–	0.89	–	0.91	0.85	0.83
SD	0.03	–	0.03	–	0.03	0.04	0.05

5 Conclusion

This article contributed to determine the relative efficiency of the Brazilian Federative Units in converting public expenditures into improvements in educational indicators between 2011 and 2014.

The efficient Brazilian States in the period were: Alagoas, Amapá, Distrito Federal, Maranhão, Piauí, Rio de Janeiro, Roraima and Amazonas. We observed the DMUs with the greatest technological changes (TC) as the ones that benefited most from the changes that occurred in the period. In addition, the DMUs that increased their technical efficiency (TE) were those able to improved their positions in the efficiency ranking.

We concluded that efficient Federative Units serve as benchmarks for the others, and where household income grew more that efficiency prevailed. On the other hand, the States that most increased their expenditures were not the most efficient.

We highlight since the beginning of the 2000s, Brazil has been experiencing significant changes in its social indicators. For future studies, we suggest the investigation of the efficiency of social programs and the use of other variables.

References

Afonso, A., Schuknecht, L., & Tanzi, V. (2005). Public sector efficiency: An international comparison. *Public Choice, 123*(3–4), 321–347.

Almeida, M. R., Mariano, E. B., & Rebelatto, D. A. N. (2006). Análise Por Envoltória De Dados-Evolução E Possibilidades De Aplicação.

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science, 30*(9), 1078–1092.

Barros, R. P. O., Foguel, M. N. O., & Ulyssea, G. O. (2006). Desigualdade de renda no Brasil: uma análise da queda recente.

Cacciamali, M. C., & Tatei, F. (2016). Mercado de trabalho: da euforia do ciclo expansivo e de inclusão social à frustração da recessão econômica. *Estudos Avançados, 30*(87), 103–121.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2*(6), 429–444.

Charnes, A., Cooper, W. W., & Rhodes, E. (1981). Evaluating program and managerial efficiency: an application of data envelopment analysis to program follow through. *Management Science, 27*(6), 668–697.

Coco, G., & Lagravinese, R. (2014). Cronyism and education performance. *Economic Modelling, 38,* 443–450.

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis*. Springer Science & Business Media.

Delgado, V. M. S., & Machado, A. F. (2007). Eficiência das escolas públicas estaduais de Minas Gerais.

Dufrechou, P. A. (2016). The efficiency of public education spending in Latin America: A comparison to high-income countries. *International Journal of Educational Development, 49,* 188–203.

Fare, R., Grosskopf, S., & Lovell, C. K. (1994). *Production frontiers*. Cambridge: Cambridge University Press.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society. Series A (General), 120*(3), 253–290.

Ferreira, C. M. C. (2009). Introdução à análise envoltória de dados: teoria, modelos e aplicações. UFV.

França, M. T. A., & Gonçalves, F. O. (2015). O FUNDEF e a eficiência na provisão municipal de ensino fundamental. Production(ahead).

Fundo Nacional de Desenvolvimento da Educação—FNDE. (2017a). Frequência Escola no Ensino Médio. Fundo Nacional de Desenvolvimento da Educação.
Fundo Nacional de Desenvolvimento da Educação—FNDE. (2017b). Investimento Educacional por aluno. Fundo Nacional de Desenvolvimento da Educação.
Fundo Nacional de Desenvolvimento da Educação—FNDE. (2017c). Receita Total em Educação. Fundo Nacional de Desenvolvimento da Educação.
Gupta, S., & Verhoeven, M. (2001). The efficiency of government expenditure: Experiences from Africa. *Journal of policy modeling, 23*(4), 433–467.
Hoffmann, R. (2013). Transferências de renda e desigualdade no Brasil (1995–2011). Programa Bolsa Família: uma década de inclusão e cidadania (pp. 207–216). Brasília: IPEA.
Instituto Brasileiro de Geografia e Estatística (IBGE), Pesquisa Nacional por Amostra de Domicílios (PNAD). 2017. Disponível em: https://www.ibge.gov.br/. Acesso em: 2017.
Kalirajan, K. P., & Shand, R. T. (1999). Frontier production functions and technical efficiency measures. *Journal of Economic surveys, 13*(2), 149–172.
Kozuń-Cieślak, G. (2013). Efektywność inwestycji publicznych w kapitał ludzki.
Lavado, R. F., & Cabanda, E. C. (2009). The efficiency of health and education expenditures in the Philippines. *Central European Journal of Operations Research, 17*(3), 275–291.
Lovell, C. (2000). *Measuring efficiency in the public sector*. Public provision and performance: contributions from efficiency and productivity measurement Amsterdam: Elsevier.
Mariano, E. B., & Rebelatto, D. A. N. (2014). Transformation of wealth produced into quality of life: Analysis of the social efficiency of nation-states with the DEA's triple index approach. *Journal of the Operational Research Society, 65*(11), 1664–1681.
OECD. (2016). Education at a Glance 2015. Organização para Cooperação e Desenvolvimento Econômico.
Oliveira, R. P. (2007). From the universalization of teaching to the challenge of quality: A historical analysis. *Educação & Sociedade, 28*(100), 661–690.
Põldaru, R., & Roots, J. (2014). A PCA–DEA approach to measure the quality of life in Estonian counties. *Socio-Economic Planning Sciences, 48*(1), 65–73.
Reig-Martínez, E. (2013). Social and economic wellbeing in Europe and the Mediterranean Basin: Building an enlarged human development indicator. *Social Indicators Research, 111*(2), 527–547.
Reig-Martínez, E. (2016). Cities and quality of life in the Metropolitan Area of Valencia. *Revista De Estudios Regionales* (106), 79–104.
Salazar Cuéllar, A. F. (2014). The efficiency of education expenditure in Latin America and lessons for Colombia. *Desarrollo y Sociedad* (74), 19–67.
Sen, A. (2001). *Development as freedom*. Oxford Paperbacks.
Tone, K. (2001). A slacks-based measure of efficiency in data envelopment analysis. *European Journal of Operational Research, 130*(3), 498–509.
UNESCO. (2016). Education for all. United Nations Educational, Scientific and Cultural Organization.
Vilela, D. L. (2004). Utilização do método analise envoltória de dados para avaliação do desempenho econômico de cooperativas de crédito. 2004. Dissertação (Mestrado em Engenharia de Produção), Universidade de São Paulo, São Carlos. p. 144.

Using Simulated Annealing to Solve the Daily Drayage Problem with Hard Time Windows

Alejandro Escudero-Santana, Manuel Cuberos-Gallardo, Jesús Muñuzuri and Pablo Cortés

Abstract Drayage is the stage of the intermodal transport that deals with transport of freight on trucks among the intermodal terminal, and customers and suppliers that are located in its hinterland. This work proposes an algorithm based on simulated annealing heuristics to solve the operations of drayage. This algorithm has been used to solve battery problems, demonstrating the validity and suitability of its results, which were compared with exact method.

Keywords Drayage · Intermodality · Simulated annealing · Hard time windows

1 Introduction

Between the different ways of carrying out the transport of goods, the highest growth is on the intermodal transport, which is a particular way of multimodality. It consists in using different modes of transport to carry a unit load. This feature allows to reduce the time the goods must spend in intermodal terminals, due to the replacement of the operations of loading and unloading of goods from a container to another by loading and unloading of containers between different means of transport.

This paper focuses on a problem of land transport, the Daily Drayage Problem (DDP). This issue provides the connection between the intermodal terminal and its hinterland, including the operations of loading and unloading containers in vehicles (Jula et al. 2005). The DDP aims to optimize the tasks of container shipments from the terminal to customers and suppliers, and viceversa. This type of problem is a specific vehicle routing problem with time windows (VRPTW), where the capacity of the vehicle is defined as a binary variable, so vehicles must be uploaded or downloaded.

A. Escudero-Santana (✉) · M. Cuberos-Gallardo · J. Muñuzuri · P. Cortés
Dpto. de Organización Industrial y Gestión de Empresas II, Escuela Técnica Superior de Ingeniería, Universidad de Sevilla, Avd. Descubrimientos s/n, 41092 Seville, Spain
e-mail: alejandroescudero@us.es

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The DDP has been solved with different methods. Caris and Janssen (2009) propose a local search heuristic, Caris and Janssen (2010) develop a simulated annealing, Smilowitz (2006) prove a roll-on horizon method, Zang et al. (2009) and Xue et al. (2014) use a tabu search, and Escudero-Santana et al. (2015) present a viral method to solve the problem. Escudero-Santana et al. (2013) use a dynamic method to solve the problem with transit time uncertainly.

This work aims to solve the daily drayage problem by means of an algorithm based on the heuristic of simulated annealing. Section 2 gives an approach of the daily drayage problem. The state of art of simulated annealing is presented in Sect. 3. The results obtained are shown in Sect. 4. Finally, several conclusions are drawn in Sect. 5.

2 Problem Description

Drayage is the beginning and the end of the intermodal transport chain. It is composed of the operations of collection and delivery of empty containers in the deposits, collecting the goods, loading and unloading in intermodal terminals, and delivery charge to the recipient. At this stage, it is considered that the trucks could be in three different states: loaded with a full container, loaded with an empty container, or without charge.

The two fundamental operations of the transport are the pick-up and delivery of containers. These operations always occur in a particular facility (client, depot or terminal). However, the movement of a container may be carrying out more operations. The need to have containers available at different points at certain times makes it essential the transport of empty containers. Also, depending on the property of the containers (containers may belong to the charger, the recipient or the company responsible for the main journey), there will be more or less empty return journeys. These movements must be reduced to the maximum with the objective of maximizing the transport load factor.

These tasks must be performed within some time windows if a good performance of the intermodal chain is required. This peculiarity makes the problem to solve to be defined as a DDPTW, where there are several tasks, T, which should be covered with a combination of vehicles, V, within certain time windows. The problem is to assign each task to a vehicle so that the generated costs are minimized.

For the formulation of the problem, several simplifications have been conducted to facilitate the modelling:

- Vehicles are similar in terms of capacity and technical characteristics.
- Fixed costs are the same for all vehicles.
- Variable costs are proportional to the distance travelled.
- There is only a deposit, which is located within the intermodal terminal.
- Only importation and exportation tasks are carried out.

3 The Simulated Annealing Algorithm

The simulated annealing (SA) algorithm is an iterative method for solving combinatorial and optimization problems (Kirkpatrick et al. 1983). The main attraction of the algorithm is its convergent behaviour to the optimum of the problem. This is achieved because the algorithm allows to accept worse quality solutions in each interaction, allowing the search not to be complete when a local optimum is found.

The algorithm is based on the process of annealing of metals and ceramics for crystallized materials, with minimum internal energy. In this process the temperature of the material rises to crystallize, thus increasing its internal power, and subsequently allowing to cool slowly. In this process of the loss of energy, the particles that make up the material move in search of positions of lower energy, thus achieving the crystallized form.

There have been some authors who have used the Simulated Annealing algorithm to find near-optimal solutions in various problems of combinatorial optimization (Chiang and Russell 1996; Eglese 1990).

3.1 Solution Encoding

The form of the solution has been considered a vector that includes numbers from 1 to $n + m$, where n is the number of tasks that should be covered and m the number of available vehicles. In the solution, each number from 1 to n corresponds to a task, while the numbers from $n + 1$ to $n + m$ correspond to vehicles. The interpretation of the solution is the following: each vehicle must cover all the tasks until another number corresponding to another vehicle is found. This is illustrated with an example in Table 1, where there are 3 vehicles that must cover 6 tasks.

3.2 Algorithm

The algorithm developed to solve de DDPTW follows the next steps:

Table 1 Examples of interpreting a matrix solution

Matrix solution	Interpretation
[7 1 2 8 3 4 5 9 6]	The vehicle 7 covers tasks 1 and 2. The vehicle 8 covers tasks 3, 4 and 5. The vehicle 9 covers task 6
[7 1 2 3 4 8 9 5 6]	The vehicle 7 covers tasks 1, 2, 3 and 4. The vehicle 8 is free. The vehicle 9 covers tasks 5 and 6

1. Firstly, an initial vector solution is randomly created, S_0. Best solution, $S_{best} = S_0$.
2. That solution is evaluated using the objective function, $f(S_0)$.
3. The neighbourhood of solution is generated, $N(S_0)$. Searching of neighbour solutions is implemented by swapping all the numbers of the current solution. Each new permutation between two numbers (either vehicles or tasks) generates a new solution.
4. A solution from the neighbourhood is randomly chosen, S' *in* $N(S_0)$, and its cost is calculated by evaluating it in the objective function $f(S')$.
5. This new solution is adopted as a solution with a probability P, depending on the improvement of the new solution with respect to the current solution, $\delta = f(S') - f(S_0)$.

- $P = 1$ if $\delta < 0$
- $P = e^{-\delta/t}$ if $\delta > 0$

6. If $\delta < 0$, then, $S_{best} = S'$
7. The process (3–5) is repeated L times for each value of t.
8. t is updated with the cooling function, $\alpha(t)$.
9. The process is repeated until the stop condition, t_{min}.

Parameters of the SA are:

- Temperature, t: temperature is a control parameter that determines the probability of accepting a new solution as one whose cost is greater than the current solution, allowing that way to escape from local minima.
- Cooling function, $\alpha(t)$: determines the speed with which the temperature decreases.
- Initial temperature, t_0: determines the value of temperature when the process starts.
- Final temperature, t_{min}: marks the algorithm stop condition.
- Length of the string, L: sets the number of iterations which the algorithm makes for each value of the temperature.

The value of parameters should be set based on the experience. In the present work, the value of L depends on the size of the problem, to allow for more thorough searches on larger problems. The values of the defined parameters are shown in Table 2. These values were selected by mean different experiments. These experiments were done on the Solomon Benchmark.

Table 2 Parameters of the algorithm

Parameter	Value
t_0	50
t_{min}	1
$\alpha(t)$	$t_{k+1} = t_k/(1 + 0.005 \cdot t_k)$
L	10

4 Results

The solved problems are part of a battery of problems generated in Escudero-Santana et al. (2015), which is an adaptation of the Benchmarking created in Solomon (1987) for the VRPTW. It is a battery of 12 Random problems (R), 9 Cluster problems (C) and 8 Random + Cluster problems (RC).

The problems have been solved by considering hard time windows where the delay in the solution are not allowed, so the total cost generated by a solution can be broken down into two distinct costs:

- Cost per distance: is the cost that is directly dependent on the total distance travelled. It has a value of 1.
- Cost per vehicle: fixed cost associated with the use of each vehicle. This cost has a value of 10 per vehicle, and will be 0 when the car is idle.

Further details of the problem are the average speed of vehicles, 60 km/h, and the time of loading and unloading, estimated both in 15 min.

Results are shown in Tables 3, 4 and 5. Every instance was runned 10 times. It is clear that the execution times increase as the size of the problem increases. However, for problems of the same size, these times are very similar, and then the computational load only depends on the size of the problem to solve, and no other variants as the random initial solution.

Table 3 Solutions of problems with 25 tasks

Test	Class R			Class C			Class RC		
	Ave. Cost	Min. Cost	Exe. Time	Ave. Cost	Min. Cost	Exe. Time	Ave. Cost	Min. Cost	Exe. Time
1	1082.40	1061.60	17.17	712.48	700.31	15.24	1483.64	1477.84	23.52
2	1028.84	1024.80	22.91	674.24	669.11	23.16	1196.23	1184.52	28.01
3	878.63	872.63	29.39	687.90	681.83	28.19	1152.57	1149.75	32.38
4	870.85	858.57	32.60	685.83	672.05	30.85	1123.01	1117.93	33.52
5	1047.00	1034.16	21.70	700.51	678.97	18.54	1400.87	1398.12	25.25
6	1000.27	994.00	25.04	740.17	735.03	16.68	1391.96	1379.84	30.96
7	971.65	968.02	29.44	683.71	673.07	19.51	1288.03	1283.02	33.56
8	936.16	929.04	31.32	656.04	649.04	32.51	1221.58	1178.61	34.58
9	955.85	949.89	26.72	680.36	669.08	26.17			
10	909.60	901.92	32.51						
11	943.31	933.33	30.60						
12	933.02	928.28	29.97						

Table 4 Solutions of problems with 50 tasks

Test	Class R			Class C			Class RC		
	Ave. Cost	Min. Cost	Exe. Time	Ave. Cost	Min. Cost	Exe. Time	Ave. Cost	Min. Cost	Exe. Time
1	2180.61	2067.84	55.60	1512.98	1488.72	45.92	3035.65	2961.35	71.22
2	1967.81	1953.58	76.98	1481.07	1459.34	69.06	2635.28	2607.01	79.72
3	1814.64	1803.51	89.71	1464.92	1450.70	82.46	2428.31	2408.62	92.74
4	1751.74	1743.88	97.05	1490.76	1481.47	90.10	2335.36	2328.00	99.38
5	1980.13	1962.87	72.10	1499.15	1476.95	51.86	3112.31	3084.84	77.13
6	1875.62	1861.08	82.57	1553.13	1523.48	56.13	3036.86	2987.29	85.23
7	1811.35	1802.20	90.14	1496.73	1482.13	58.32	2613.20	2568.27	99.70
8	1736.29	1724.52	97.41	1424.04	1408.66	93.19	2540.98	2439.32	100.27
9	1860.88	949.89	86.23	680.36	669.08	78.58			
10	1822.91	901.92	99.29						
11	1789.42	933.33	99.00						
12	1772.77	928.28	99.85						

Table 5 Solutions of problems with 100 tasks

Test	Class R			Class C			Class RC		
	Ave. Cost	Min. Cost	Exe. Time	Ave. Cost	Min. Cost	Exe. Time	Ave. Cost	Min. Cost	Exe. Time
1	3923.88	3858.50	206.63	3648.29	3587.18	183.88	4825.37	4729.63	251.85
2	3642.99	3584.55	270.91	3559.44	3491.33	260.82	4356.98	4293.25	312.33
3	3285.65	3258.15	338.09	3467.24	3424.08	323.41	4088.93	4043.49	343.73
4	3165.90	3144.81	384.41	3427.53	3401.51	361.84	4037.85	3998.86	368.07
5	3599.15	3544.08	256.46	3662.17	3582.56	198.37	4849.72	4740.79	302.30
6	3462.41	3424.64	315.75	3527.42	3471.54	283.27	4718.19	4543.67	331.38
7	3259.01	3236.06	339.87	3572.76	3505.77	235.40	4283.26	4234.76	371.39
8	3145.32	3121.36	370.67	3339.09	3327.02	374.37	4145.33	4105.18	389.17
9	3412.79	3356.38	319.47	3464.77	3431.89	296.95			
10	3307.31	3245.70	359.75						
11	3401.02	3373.58	354.43						
12	3203.80	3167.17	379.95						

In Table 6 a comparison between SA results and the results of exact method (Gurobi) is shown. Gurobi use different methods as heuristics, branch and bound and cutting planes. It is important to consider that Gurobi present a tolerance of $10e^{-4}$ on the constraints. Despite this, gap between SA and Gurobi is low. On execution time, Gurobi was tested with test R3. Result of Gurobi for 25 tasks is 872.63 with an execution time of 105.29 s; for 50 tasks, the best result reaches by Gurobi after one hour is 1784.31 (SA present a gap of 0.01%), and for 100 tasks the best result provides by Gurobi in one hour is 3928.68 (result of SA is 3258.15).

Table 6 SA algorithm versus exact method (Class R—25 tasks)

	SA	Gurobi	Gap (%)
R25-1	1061.60	1061.60	0.00
R25-2	1024.80	1009.66	1.48
R25-3	872.63	862.63	1.15
R25-4	858.57	848.10	1.22
R25-5	1034.16	1023.36	1.04
R25-6	994.00	985.41	0.86
R25-7	968.02	965.33	0.28
R25-8	929.04	919.03	1.08
R25-9	949.89	939.88	1.05
R25-10	901.92	891.92	1.11
R25-11	933.33	931.72	0.17
R25-12	928.28	919.95	0.90

5 Conclusion

Simulated Annealing is a widely used meta-heuristic in the resolution of optimisation problems. Several research papers have been able to verify its usefulness. A great advantage is its proved convergence to optimum. The convergence is achieved through a process of slow cooling. It involves high execution times, and thus, computational cost of the algorithm that can not be assumed. So, an adequate setting of the parameters is extremely important, mainly both the cooling function and the length of the spring, so that an equilibrium between computational cost and goodness of the solution could be accomplished.

Related to the DDPTW, it is necessary to analyse the suitability of the algorithm with regard to this kind of problems. Analysing the reached results, it is concluded the algorithm achieves satisfactory results in comparison with the classical heuristic, in spite of its greater computational cost. Therefore, the application of SA to solve the DDPTW is appropriate for solving problems without an excessive level of response time, such as the planning of daily routes. Nevertheless, it is not suitable to solve real-time problems.

An important concern about the usefulness of SA in the field of drayage is its convergence. So, this method could be used as a comparison tool for future development.

References

Caris, A., & Janssens, G. K. (2009). A local search heuristic for the pre- and end-haulage of intermodal container terminals. *Computers & Operations Research, 36*(10), 2763–2772.

Caris, A., & Janssens, G. K. (2010). A deterministic annealing algorithm for the pre- and end-haulage of intermodal container terminals. *International Journal of Computer Aided Engineering and Technology, 2*(4), 340–355.

Chiang, W. C., & Russell, R. A. (1996). Simulated annealing metaheuristics for the vehicle routing problem with time windows. *Annals of Operations Research, 63*(1), 3–27.

Eglese, R. W. (1990). Simulated annealing: A tool for operational research. *European Journal of Operational Research, 46,* 271–281.

Escudero-Santana, A., Munuzuri, J., Cortes, P., & Aparicio, P. (2015). A viral system to optimise the daily drayage problem. *International Journal of Bio-Inspired Computation, 3*(7), 176–182.

Escudero-Santana, A., Munuzuri, J., Guadix, J., & Arango, C. (2013). Dynamic approach to solve the daily drayage problem with transit time uncertainty. *Computers in Industry, 62*(2), 165–175.

Jula, H., Dessouky, M. M., Ioannou, P., & Chassiakos, A. (2005). Container movement by trucks in metropolitan networks: Modeling and optimization. *Transportation Research Part E, 41*(3), 235–259.

Kirkpatrick, S., Gelatt, C. D., & Vecchi, M. P. (1983). Optimization by simulated annealing. *Science, 220*(4598), 671–680.

Smilowitz, K. (2006). Multi-resource routing with flexible tasks: An application in drayage operations. *IIE Transactions Institute of Industrial Engineers, 38*(7), 570–590.

Solomon, M. (1987). Algorithms for the vehicle routing and scheduling problems with time window constraints. *Operations Research, 35*(2), 254–265.

Xue, Z., Zhang, C., Lin, W. H., Miao, L., & Yang, P. (2014). A tabu search heuristic for the local container drayage problem under a new operation mode. *Transportation Research Part E, 62,* 136–150.

Zhang, R., Yun, W. Y., & Moon, I. (2009). A reactive tabu search algorithm for the multi-depot container truck transportation problem. *Transportation Research Part E, 45*(6), 904–914.

Modeling and Simulation of Operations: A Case Study in a Port Terminal of Vale S/A

I. Agostino, S. Sousa, P. Frota, R. Daher and A. M. Souza

Abstract This paper addresses the development of a simulation model of operations in the train arrival process at Port Terminal of Ponta da Madeira, aiming to develop a simulation model to support decision making. The case study was used in this study as technical procedure, for the understanding of the theoretical concepts in a practical situation. At the end of the study, it was possible to verify that the developed model presented adherence to actual behavior of the system studied, being valid for the operationalization, as a tool to support decision making.

Keywords Discrete event simulation · Operational research · Port operation

I. Agostino (✉)
Department of Industrial Engineering, University of Santa Maria,
Santa Maria, RS 97105900, Brazil
e-mail: icaroagostino@gmail.com

S. Sousa
Department of Industrial Engineering, University of Pernambuco,
Caruaru, PE 55014900, Brazil
e-mail: saymon.ricardo.sousa@gmail.com

P. Frota
Department of Operations Management of Maritime Terminal
of Ponta da Madeira, Vale S/A, São Luís, MA 65085581, Brazil
e-mail: pedro.frota@vale.com

R. Daher
Department of Industrial Engineering, Ceuma University,
São Luís, MA 65020570, Brazil
e-mail: ricardo.daher@hotmail.com

A. M. Souza
Department of Statistic, University of Santa Maria, Santa Maria,
RS 97105900, Brazil
e-mail: amsouza.sm@gmail.com

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1 Introduction

The current economic situation in Brazil, followed by constant technological developments, has imposed to organizations in diverse sectors the continuous search for the best way to operate its processes, independent of the nature that they belong. Thus, the decision-making processes in organizations constantly needs subsidies that stimulate the correct analysis of the constituent elements of the decision-making process, presenting the mathematical methods with wide applicability and relevance for this theme.

In this scenario, simulation techniques are presented with the purpose of solving diverse problems involving risks, as well as creating subsidies that assist decision makers in formulating strategies in the productive processes, defining better ways to use limited resources, concerning with the efficiency in their use. Through the advances of the studies in the area, the application of simulation techniques for decision support has presented a strong relevance for the academic environment and for the organizational environment (Chwif and Medina 2015).

Considering the theme addressed in this research, this paper has the main purpose: to verify how the development of a simulation model could contribute to the decision-making process in a port activity? Such a questioning must require mechanisms of observation and information gathering capable of allowing that the research topic reach the general aim of the research that is: To verify how the development of a simulation model could contribute to the decision-making process in a port activity.

2 Theoretical Fundamentals

In this topic, theoretical aspects are provided to support the research, structured in decision-making in organizational processes and discrete event simulation issues.

2.1 Decision-Making in Organizational Processes

The information created by organizations is part of the cultural, scientific, technological and conjectural knowledge. Whatever the type of knowledge, the information consists in the transmission of value judgment, through organized and measured data. The need of a wide view of the structure and dynamic information is a valuable tool, because it can provide a control of various parameters that react to their dynamics (Spinola and Pessôa 2010, p. 85).

The organizational field is very fertile and favorable for the application of formal methods and procedures for analysis of decision issues. It is known that the decision making is one of the main elements that differs managers of other employees in the company, because making decisions is presumably the greatest activity of any manager. Decision making embraces a problem situation, where managers are faced against several alternative solutions. Every decision problem has a set of information which the problem should be analyzed, in generally using a directed of mathematical models effect (Moreira 2013, p. 23).

2.2 Discrete Event Simulation

Computational simulation can be classified into three categories: Monte Carlo simulation, where random number generators are used to simulate mathematical systems or physical where time is not clearly considered as a variable; continuous simulation is used to model systems which the state varies continuously in time; and the discrete events simulation that are guided by events, taking into consideration how system state changes over time (Chwif and Medina 2015, p. 6).

In this context, Prado (2014, p. 27) states that production systems present wide application field of the simulation methods, because many situations are fitted in this context, from changes in existing operations systems, such as expansion from the exchange or addition of equipment that affect the dynamics process, being able to anticipate where bottlenecks are formed; by planning of the new complete production sectors, obtaining the best alternatives for this, within several other questions involving the production function of the organizations.

The discrete events simulation works with the relation of the reality in its whole context (which include unexpected, hypotheses, possibilities, uncertainties) and with experimental ideas, which offers to engineer and every manager the alternative of "testing" all these ideas by computer programs (computational simulation) in order to offer results, or options, that introduce the decisive, managerial and administrative product process that will be executed in an organization (Chwif and Medina 2015, pp. 1–6).

3 Methodology

The research used as technical procedure the case study, focused on the collection and registration of information on one specific cases, elaborating organized and controlled critical reports, allowing decisions and interventions about the object of investigation (Barros and Lehfeld 2000, p. 95).

For the development of the simulation model was adopted the methodology proposed by Chwif and Medina (2015, p. 10), which is divided into three basic stages: conception or model formulation, model implementation and analysis of the model results. In the first stage, the system to be simulated is studied, to define the model scope. The input data are collected in this stage, and finally developed a conceptual model, schematically representing the actual model.

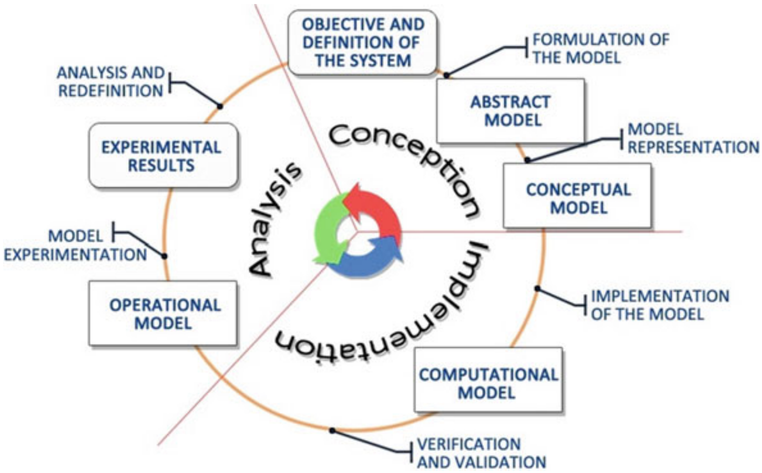

Fig. 1 Simulation methodology. Adapted from Chwif and Medina (2015, p. 11)

In the second stage, "implementation", the conceptual model is converted into a computer model by using specific software. For this study the software used was the Arena Simulator version 14.7, because it was already available for the utilization in a company environment, as well as it is one of the most used software on current days. Then the computer model must be compared to the real model, in order to validate its future utilization, the validation of this model in this case will be given by comparison of results generated from the simulation with real system parameters.

In the third stage, systematic experiments are performed, to guarantee the model efficiency creating subsidies for modifications and in case of unsatisfactory model as an analytic tool. The image below represents in a schematic way the methodology proposed by the authors (Fig. 1).

4 Case Study

The study was developed within a Port Operations Management, simulating part of an integrated logistic system of iron ore handling (containing mine, railroad and port), discharging all the production of the Carajás mine (Brazil), which is currently considered the largest open-pit mining in the world. The material transportation, after extraction, is performed via rail system composed of three lots of 110 wagons forming a composition of 330 wagons.

The initial port process is characterized by ore unloading using Wagon Tippler, where the industrial equipment turns one wagon pair at a time, directing the material to a system of conveyor belts. The proposed model contemplates part of the unloading ore operation, covering the processes: train arrival, queuing, rail handling and unloading.

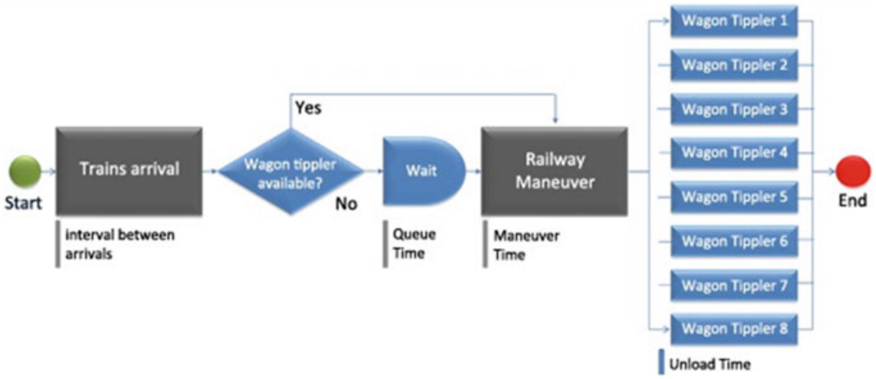

Fig. 2 Conceptual model

4.1 Conceptual Model

The construction of the conceptual model supports the elaboration of model simulation, which the relation among the input process, processing and output process, as well as the conceptual flow of the real system studied, with the necessary simplifications, will be evidenced (Fig. 2).

The model will include the following processes: (1) Trains arrival, characterized by the interval between arrivals; (2) Verification of the availability of a Wagon tippler, characterized by a decision module that verifies the availability of the machine, since the actual system does not allow queue formation "in the equipment", but before the process; (3) Wait for availability; (4) Railway maneuver, characterized by the physical process of moving the lot of wagons to the turning positioning of the wagon tippler; (5) Unloading process in the wagon tippler.

4.2 Collection, Processing and Modeling Data

According to Chwif and Medina (2015, pp. 24–25), the modeling study is presented as fundamental step in the process of developing a simulation model, being characterized by obtaining probabilistic models that represent a particular random phenomenon, and it can be summarized in 3 steps: data collection, data processing, statistical inference.

The data collection was performed via intern in the company system, which is fed automatically by automation process. The time analyzed correspond a one month of operation, and to assure the model assertiveness, the month of September 2016 was considered as calculation basis.

The data were modeled by statistical inference, from the Input Analyzer tool, complementing the Arena Software. In the data pre-treatment process, outliers were

Table 1 Criteria for classification of *p*-value

Value (significance level)	Criteria
p-value < 0.01	Strong evidence against the adhesion hypothesis
0.01 $\leq$ *p*-value < 0.05	Moderate evidence against adherence hypothesis
0.05 $\leq$ *p*-value < 0.10	Potential evidence against adherence hypothesis
0.10 $\leq$ *p*-value	Weak or non-existent evidence against adherence hypothesis

eliminated and the sample size was adequate, as suggested by the technical literature (Chwif and Medina 2015, p. 28).

The data were stratified by operation turn and wagon tippler, in order to have reliability in the reliable retraction of the simulated system. The following data were modeled: TUT behavior (Total Unloading Time) of each WT (wagon tippler), such information represents the time that wagon tippler takes to unload a lot with 110 wagons; the interval between lots arrival, it represents the time between the arrival of lots in the system, for that it was modeled the three operation turns; total maneuver time, that represents the time that the locomotive takes to handle the input system lot to the position inside the wagon tippler.

All the entrances were modeled by the Input Analyzer, which the best distribution curve was defined by the minimum "mean squared deviation" in relation to the theoretical curve. The data adjustment was performed using the Kolmogorov-Smirnov test, which compares if the observed model adheres to the theoretical model, using the *p-value* parameter following the principles in the Table 1 (Chwif and Medina 2015, p. 36).

After modeling, adjustment and adherence validation of the distributions in relation to the theoretical curves, the following results were obtained, as shown in Table 2.

The data modeling presented the behavior already expected in the literature, and the data arrival of the intervals behaved in a negative exponential distribution, which has as most common applications events of successive occurrences between arrivals. For the process time data, the "total unloading time" of all the turners presented a behavior in the Erlang distribution, common for service events, and the "total maneuver time" obtained normal distribution behavior, common to operating times. All distributions behaved with sufficient adhesion levels for adequacy validation, and for the *p-value,* positive results were also obtained, since no adhesion hypothesis was refuted (Chwif and Medina 2015, pp. 261–271).

4.3 Computational Model (Arena)

The model built in Arena is similar to a flowchart, presenting a "simulated" form of the actual layout (Fig. 3).

Table 2 Input data modeling

Sample of data	Adherent curve	Curve parameters	Square error	*p*-value
TUT of WT1	Erlang	91 + ERLA(12.2, 2)	0.00478	0.256
TUT of WT2	Erlang	90 + ERLA(12.2, 2)	0.00263	0.457
TUT of WT3	Erlang	90 + ERLA(12.2, 2)	0.00161	0.447
TUT of WT4	Erlang	89 + ERLA(12.2, 2)	0.00162	0.390
TUT of WT5	Erlang	89 + ERLA(12.2, 2)	0.00656	0.207
TUT of WT6	Erlang	89 + ERLA(12.2, 2)	0.00643	0.369
TUT of WT7	Erlang	90 + ERLA(12.2, 2)	0.00660	0.106
TUT of WT8	Erlang	90 + ERLA(12.2, 2)	0.00660	0.160
Arrival interval (07 × 15)	Exponential (−)	−0.001 + EXPO(39.3)	0.01280	0.102
Arrival interval (15 × 23)	Exponential (−)	−0.001 + EXPO(28.5)	0.00583	0.209
Arrival interval (23 × 07)	Exponential (−)	−0.001 + EXPO(37.1)	0.00907	0.122
Maneuver total time	Normal	NORM(31.8, 4.59)	0.02890	0.220

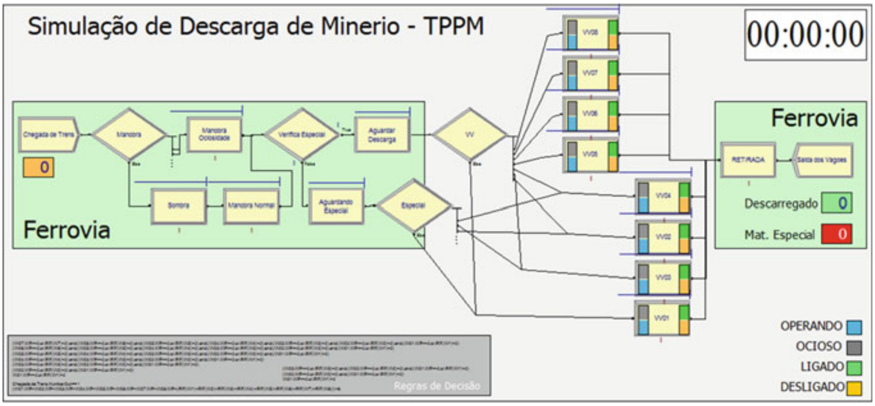

Fig. 3 Computational model (Arena)

The model contemplated all the real steps, as well as the decision steps for targeting to each specific equipment, a visual indicator was inserted in each wagon tippler, with real time status, using color system to simplify the identification.

4.4 Model Validation

The validation of the fit model will be done by comparing the results obtained from the simulation with the official result of the same parameters of September 2016, which was used as a basis for modeling the input data.

Table 3 Comparação entre dados reais e valores simulados

Parameters	Value (min)	Percentage (%)
Average awaiting unload	40.2	100.0
Simulated result	42.1	104.7

The validation determined by comparing simulated and actual results is presented as ideal when occurs a basic system (actual and working) that gives such information, which the system can replace the basic system to experimentation. In this case the analytic comparison between actual and simulated offer subsidies that can infer the validation of the developed model.

The indicator selected to infer the validation of the system was "Waiting for Unloading", which represents the average time per lot, in which the lot had to wait for the availability of the toner in an operation day. The simulated result presents a value 4.72% higher than the real one. Therefore, it is considered that with the simulated values, it can infer the studied system (Table 3).

5 Final Considerations

The development of the simulation model was successful, once that in the end of the project it was reached the general aim of developing a tool to support decision making, by simulating discrete events using the Arena Software, simulating the arrival of trains and the unloading process with different situations and premises that can generate subsidies that helps decision making.

The developed model followed the concepts and definition of the technical literature, as shown through the project, assuring the scientificity of the developed model. Regarding the adherence of the model to reality, the percentage reached (104.72%) represents a high adherence result, guaranteeing the fidelity of the model to reality, considering that the simplifications performed do not compromise the quality of the subsidies generated.

The delivered model shows an easy user interface with low execution time of the situations, being an easy and fast tool. As future studies, it is recommended advance of the simulator to the storage yards and queues ships, contemplating the whole port terminal operation including port and rail interface, as well as port and ships.

References

Barros, A. J. S., & Lehfeld, N. A. S. (2000). *Fundamentals of scientific methodology*. São Paulo: Pearson Education.

Chwif, L., & Medina, A. (2015). *Modeling and simulation of discrete events: Theory & application*. Rio de Janeiro: Elsevier.

Moreira, D. A. (2013). *Production management and operations*. São Paulo: Cengage Learning.

Prado, D. S. (2014). *Using the Arena in simulation*. São Paulo: Falconi.

Spinola, M. M., & Pessôa, M. S. P. (2010). Information technology. In: J. C. Contador (Organizer), *Operations management: Industrial engineering for the modernization of the company*. São Paulo: Blucher.

The Economic Viability of Second-Generation Ethanol in Coming Years

M. Carvalho and L. Ishikawa

Abstract Second-generation ethanol is a biofuel derivate from lignocellulose sources that promotes greater savings and it is an environmental friendly option. However, this new technology still has some gaps that must be overcome such as low yield of raw material conversion and high production costs. Using a study developed by a Brazilian research institute and simulations in different scenarios over time; the present paper has the objective to reinforce the competitive potential of second-generation ethanol. The results demonstrate the potential of improve efficiency and reduce production costs in different technological scenarios.

Keywords Second-generation ethanol · Biofuels · Energy efficiency
Resource optimization · Sustainability

1 Introduction

Biofuels are renewable energy source produced from biomass; which means, they are organic matter derived from plants that can be converted directly into liquid fuels. Biofuels were developed with the objective to replace partially or totally the non-renewable fuels like crude oil derivate. Besides that, they considering economic, environmental, and social factors in their production. The first generation of biofuel uses as feedstock any plant rich in carbohydrates or starch such as beet, canola, corn, soy, sugar cane, wheat, palm oil, animal fats, and cooking oils. The new generation uses lignocellulose as raw material (Dufey 2006; Davis et al. 2008; Dale 2010; Bandyopadhyay 2015; Larson 2008).

M. Carvalho · L. Ishikawa (✉)
Escola Superior de Engenharia e Gestão, Rua Vergueiro, 1951—Vila Mariana,
São Paulo, SP 04101-000, Brazil
e-mail: ishikawaleticia@gmail.com

M. Carvalho
e-mail: marcelod@eseg.edu.br

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The cellulosic ethanol is a second-generation biofuel that comes up as a promise to be another option to replace fossil fuels once promotes greater savings and it can increase the environmental liability due to a better use of resources. In Brazil, there is a large amount of biomass available since the country has the possibility to use byproduct of first generation ethanol production such as bagasse and sugar cane straw. Besides that, there is an existing demand for ethanol in addition to the country's experience with the sugar and ethanol industry for more than thirty year makes Brazil extremely favorable for the development of this new technology. All these factors might contribute to improve the current situation of the stagnation of Brazilian first-generation plants due the low investment in new facilities and the stagnation of productivity observed in recent years (Aziakou et al. 2016; UNICA 2016).

However, to make the industrial scale economically viable there is some challenges that must be overcome. Therefore, this paper presents evidences of the competitive potential of this new technology using a study and simulations of possible scenarios in Brazilian plants over time to demonstrate the economic viability of second-generation ethanol in coming years.

2 Literature Review

The first and second-generation ethanol has the same composition, however there is a difference in the raw material used. The conventional ethanol is the product of sucrose fermentation and the new method is derived from cellulosic and hemicellulose fermentation. The most common feedstock used is corn, wheat and rice straw, sugar cane residues, sorghum bagasse, grasses, and forest residues. Because of the structure of the raw material two additional phases are required: pre-treatment and hydrolysis. The first disorganize the lignocellulose complex and separate the elements (cellulose, hemicellulose, and lignin). And the second is responsible to broken the poly carbohydrates into molecules of glucose (Sticklen 2008; Naik et al. 2010; Lennartsson et al. 2014; Basso et al. 2013; Losordo et al. 2016).

When compared with other fuels already established on the market such as gasoline and first generation ethanol; the cellulosic ethanol contributes to reduce the dependency of crude oil and promotes the best use of raw material due to it uses agricultural waste. Besides that, it can increase productivity by up to 50% without expanding the area of cultivation. In addition, it can reduce the carbon emission in the atmosphere due to the better use of the raw material (Ereno 2007; Milanez and Nyko 2012; Martins and Augusto 2017; Nyko 2015; Pinto 2008).

Currently, there are six companies in the world that research and produce cellulosic ethanol in industrial scale: Abengoa (U.S.), Beta Renewables (Italy), DuPont (U.S.), GranBio (Brazil), Poet-DSM (U.S.) and Raízen (Brazil). However, none of them could achieve the capacity and maintain the production stable due to some challenges related to the improvement of enzymes. Because it is a solid and non-soluble biomass, the enzymes act in an interaction between solid and liquid, which confers complexity to the process. In addition, it is estimated that at least twenty-five different enzymes are required for complete degradation of the plant structure. Another factor is to make a single microorganism produce all in the most efficient way including on an industrial scale (Abengoa Bioenergy 2017; Beta-Renewables 2017; Dupont 2017; Granbio 2017; Poet-DSM 2017; Raízen 2017; CNPEM (Centro Nacional de Pesquisa em Energia e Materiais) 2016; EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária) 2014).

In addition to the challenges with the improvement of enzymes, companies have reported obstacles with the production process as the high degree of impurities contained in the raw material due to the use of inadequate equipment, since they were originally created for the pulp industry. The fermentation processes are five to ten times longer and Saccharomyces cerevisiae yeast can not process xylose, sugar from hemicellulose. The companies also report that equipment should be improved as they are subjected to high pressure and velocity during pre-treatment. Another factor is the low yield with the hydrolysis, which is 20–30% lower than expected (CNPEM (Centro Nacional de Pesquisa em Energia e Materiais) 2016; EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária) 2014).

If these obstacles are solved, the second-generation ethanol could be economic viable and turns to an alternative for the stagnation of Brazilian plants. In addition, this biofuel can replace the used of oil.

3 Methods

According to the article, the authors divided the total cost of ethanol into operational costs and invested capital. The first includes the cost of the enzymes and raw material. In the case of first-generation ethanol the enzyme it is not present because it is unnecessary in the production process. The second represents the annual outlay required to remunerate the investment at a minimum attractiveness rate of 12% per year for the period considered in the study. In case of Brazilian mills, the total cost of traditional ethanol is composed by 70% of raw material and 30% of capital. For the ethanol 2G, it is assumed that the cost of capital, enzyme, and raw material consist of 50, 25, and 25%, respectively. Using as an example scenario 7, the production cost of 1G and 2G ethanol it is R$ 1.159 and R$ 1.475, respectively. For conventional ethanol, R$ 0.811 of R$ 1.159 consist in 70% the cost of the raw material, and R$ 0.348 of R$ 1.159 express 30% the cost of capital. For cellulose ethanol, R$ 0.738 of R$ 1.475 represents 50% the cost of capital, and R$ 0.369 of R$ 1.475 it is the portion of the 25% for biomass and 25% for the enzyme (De Souza 2017).

With the view to verify the price variation, the previous article was used as a reference to simulate the optimistic and pessimistic scenarios. Based on sensitivity analysis of the study, a percentage variation of 30% was applied to the components of the cost of production. It was decided do not apply the variation in the cost of the raw material since Brazil already has a competitive advantage in this aspect. For traditional ethanol, R$ 0.104 of R$ 0.348 it equals to 30%. For cellulosic ethanol, 30% of R$ 0.738 results in R$ 0.214; and 30% of R$ 0.369 (concerning the cost of enzymes) is equal to R$ 0.111. In the optimistic situation, a reduction of 30% was applied. In the first situation, it was consider a reduction in the cost of capital. For ethanol 1G, subtract R$ 0.104 from R$ 0.348 and sum to R$ 0.811 it is equal to R$ 1.055. For 2G ethanol, reduce R$ 0.214 from R$ 0.738. This result plus two times R$ 0.369 results in R$ 1.262. In the second situation, the same rate was applied to the cost of the enzyme. Thus, for second-generation ethanol, subtract R$ 0.111 from R$ 0.369 and sum this result with R$ 0.738 and R$ 0.369 it is equal to R$ 1.365. In the third situation, there was a reduction in the cost of capital and the enzyme simultaneously. Therefore, for ethanol of 2G, deduct R$ 0.214 from R$ 0.738 and R$ 0.111 from R$ 0.369 and the two results plus R$ 0.369 perform the cost of R$ 1.151. In the same way for the pessimistic situation, an increased rate was applied using the variation of 30%.

4 Results

In order to demonstrate the economic viability of cellulosic ethanol in the near future two Brazilian institutions called Laboratório Nacional de Ciência e Tecnologia do Bioetanol (CTBE) and Banco Nacional de Desenvolvimento Ecônomico e Social (BNDES) conducted a study to estimate the cost of ethanol production in short, medium and long term. For this purpose, a computer simulation platform capable of evaluating different routes and technologies in the sugarcane industry was used considering environmental, economic, and social spheres. Fourteen scenarios were established according to the time horizon, the technological method used, and the type of plant. The data referring to agricultural productivity and industrial parameters were collected from several companies in the Brazilian sugarcane industry concentrated in the central-south region of the country. Afterward, they were adding into simulation platform resulting in the costs of ethanol 2G that can be finding in the Table 2 (Milanez et al. 2015) (Table 1).

Table 1 Biomass processed per year (Milanez et al. 2015)

	Scenarios	Crop	Off-season
Short term	0	2 Mt of sugarcane	–
	1, 4	4 Mt of sugarcane 0.25 Mt of dry base	–
	7	0.42 Mt of dry base	–
Midterm	2, 5A, 5B	4 Mt of sugarcane 0.34 Mt of dry base	1.72 Mt of energy cane
	8A, 8B	4.38 Mt of energy cane	–
Long term	3, 6A, 6B	4 Mt of sugarcane 0.39 Mt of dry base 1.50 of energy cane	2.67 Mt of energy cane
	9A, 9B	6.78 Mt of energy cane	–

Scenario 0 represents the base, that is, a current plant characteristic of the south-central region of Brazil with the capacity to process approximately two million tons of cane per crop using an area of twenty-five thousand hectares. Scenarios 1, 2, and 3 illustrate plants that produce first-generation ethanol. Scenarios 4, 5A, 5B, 6A, and 6B reproduce the conventional ethanol plants integrated with the second-generation ethanol plants. Scenarios 7, 8A, 8B, 9A, and 9B are equivalent to second-generation plants independent (Milanez et al. 2015).

In the short term (scenario 1), the facility has the capacity to process four million tons of sugarcane and an additional 0.25 ton of dry base per crop. In the medium term (scenario 2), the plant has the capacity to process 4 million ton of sugarcane, 0.34 ton of dry base per crop, and 1.72 million ton of sugarcane in the off-season period. In the long term (scenario 3), the capacity will increase to 4 million ton of sugarcane, 0.39 million ton of dry base, 1.5 million ton of energy cane per crop, and 2.67 million ton of sugarcane in the off-season period. Two types of technology routes were considered with fermentation separated from glucose (route A) or with co-fermentation of sugars glucose and xylose (route B). Scenario 4 represents short-term mills with a capacity similar to scenario 1. Likewise, scenarios 5A and 5B correspond to medium-term mills with a capacity similar to scenario 2. Scenarios 6A and 6B reflect mills in long term with capacity similar to scenario 3. In the short term (scenario 7) there is a processing of 0.42 million ton of dry basis. The scenarios 8A and 8B represent medium term and there is a processing of 4.38 million ton of energy cane. Scenarios 9A and 9B represents long term and there is a processing of 6.78 million ton of energy cane (Milanez et al. 2015).

According to the study, second-generation ethanol may be feasible in 2020. The current cost is approximately to R$ 1.50 per l of fuel and this value can reach R$ 0.75. In long term, this value can be reduced to R$ 0.52 making ethanol competitive even if the international price of crude oil reaches a minimum of US$ 44 per barrel

Table 2 Estimating production costs of ethanol 1G and 2G in different scenarios (Milanez et al. 2015)

Scenario	1G (R$/l)	2G (R$/l)
0	1.091	–
1	1.159	–
4	1.159	1.528
7	1.159	1.475
2	0.845	–
5A	0.845	0.769
5B	0.845	0.742
8A	0.845	0.727
8B	0.845	0.675
3	0.756	–
6A	0.756	0.550
6B	0.756	0.521
9A	0.756	0.524
9B	0.756	0.521

Table 3 Simulation optimistic and pessimistic scenarios in R$ per liter

Scenario	1G O1	2G O1	2G O2	2G O3	1G P1	2G P1	2G P2	2G P3
0	1.091	–	–	–	1.091	–	–	–
1	1.055	–	–	–	1.263	–	–	–
4	1.055	1.299	1.413	1.184	1.263	1.757	1.643	1.872
7	1.055	1.254	1.364	1.143	1.263	1.696	1.586	1.807
2	0.769	–	–	–	0.921	–	–	–
5A	0.769	0.654	0.711	0.596	0.921	0.884	0.827	0.942
5B	0.769	0.631	0.686	0.575	0.921	0.853	0.798	0.909
8A	0.769	0.618	0.672	0.563	0.921	0.836	0.782	0.891
8B	0.769	0.574	0.624	0.523	0.921	0.776	0.726	0.827
3	0.688	–	–	–	0.824	–	–	–
6A	0.688	0.468	0.509	0.426	0.824	0.633	0.591	0.674
6B	0.688	0.443	0.482	0.404	0.824	0.599	0.560	0.638
9A	0.688	0.445	0.485	0.406	0.824	0.603	0.563	0.642
9B	0.688	0.443	0.482	0.404	0.824	0.599	0.560	0.638

(Milanez et al. 2015). Based on the previous study, the optimistic and pessimistic situations were simulated in order to verify the price variation of second-generation ethanol and the results could be finding in Table 3.

According to Table 3, it is noted that government incentives and technological innovations of the enzymes would make ethanol more competitive in a reduced time. For example, the cost of second-generation ethanol can achieve R$ 0.57 in mid-term instead of long-term. Besides that, in long term this value can be reduced to R$ 0.40. Even in the pessimistic scenario, the cost of second-generation ethanol remains below the cost of first generation ethanol in some cases.

5 Conclusion

Despite the benefits of the cellulosic ethanol such as the best use of raw material, the better productivity and the possibility to reduce the carbon emission in the atmosphere; the cost of production is still high and is not enough to recover the return on investment. However, the study and the simulations showed a very optimistic scenario with the possibility the production may be feasible at Brazilian mills starting in 2020. This reality just can be possible with improvements in pretreatment, enzymatic performance, enzyme price, and fermentation efficiency that are able to reduce the total costs of producing cellulosic ethanol.

This study presented as limitations the lack of more specific data related to one of the Brazilian companies that currently produces ethanol from cellulose on a commercial scale. This analysis aimed to understand how the company reached a certain cost of sale and production. Therefore, as recommendations for future work, it would be interesting to obtain internal data and further study the costs of domestic and international companies. Also a comparative analysis of the economic feasibility of installing a mill to produce ethanol from cellulose in view of the possibility of cogeneration of energy, since the sugarcane bagasse can be used for burning with the sale of surplus energy to concessionary companies.

References

Abengoa Bioenergy. (2017). General Information. Available in: http://www.abengoabioenergy.com/web/en/2g_hugoton_project/.

Aziakou, J., et al. (2016). Produção de etanol de segunda geração: uma oportunidade histórica. Available in: https://www.knowledgeatwharton.com.br/article/producao-de-etanol-de-segunda-geracao-uma-oportunidade-historica/.

Bandyopadhyay, K. R., Dr. (2015). *Biofuel promotion in India for transport: Exploring the grey areas*. The Energy and Resources Institute, 1–11.

Basso, T. P., Basso, T. O., Gallo, C. R., & Basso, L. C. (2013). *Towards the production of second generation ethanol from sugarcane bagasse in Brazil*.

Beta-Renewables. (2017). Proesa. Available in: http://www.betarenewables.com/en/proesa/what-is-it.

CNPEM (Centro Nacional de Pesquisa em Energia e Materiais). (2016). Futuro brilhante do etanol celulósico está ameaçado. Available in: http://cnpem.br/futuro-brilhante-etanol-celulosico-esta-ameacado/.

Dale, V. H., et al. (2010). *Biofuels: Implications for land use and biodiversity* (pp. 1–13). The Ecological Society of America.

Davis, S. C., Anderson-Teixeira, K. J., & DeLucia, E. H. (2008). Life-cycle analysis and the ecology of biofuels, 1–7.

De Souza, L. C. (2017). Available in: https://www.embrapa.br/documents/1355063/8134956/Palestra+Luciano+Cunha/0a0b8954-7253-4594-a8b4-cf5ab909876c.

Dufey, A. (2006). *Biofuels production, trade and sustainable development: Emerging issues*. International Institute for Environment and Development.

Dupont. (2017). Dupont Cellulosic ethanol. Available in: http://www.dupont.com/products-and-services/industrial-biotechnology/advanced-biofuels/cellulosic-ethanol.html.

EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária). (2014). Etanol 2G depende do aprimoramento de enzimas. Available in: https://www.embrapa.br/busca-de-noticias/-/noticia/1917538/etanol-2g-depende-do-aprimoramento-de-enzimas.

Ereno, D. (2007). Álcool de Celulose. Available in: http://revistapesquisa.fapesp.br/2007/03/01/alcool-de-celulose/.

Granbio. (2017). Bioflex I. Available in: http://www.granbio.com.br/conteudos/biocombustiveis/.

Larson, E. D., Dr. (2008). *Biofuel production technologies: Status, prospects and implications for trade and development*.

Lennartsson, P. R., Erlandsson, P., & Taherzadeh, M. J. (2014). Integration of the first and second generation bioethanol processes and the importance of by-products. *Bioresource Technology, 165,* 3–8.

Losordo, Z., et al. (2016). Cost competitive second-generation ethanol production from hemicellulose in a Brazilian sugarcane biorefinery. *Biofuels, Bioproducts and Biorefining, 10*(5), 589–602.

Martins, D., & Augusto, C. (2017). Geração sustentável. Available in: http://www.anprotec.org.br/Relata/Locus/68-69/10%20desafio_Locus_68_69.pdf.

Milanez, A. Y., & Nyko, D. (2012). O futuro do setor sucroenergético e o papel do BNDES. *BNDES 60 anos, 2*, 62–87.

Milanez, A. Y., et al. (2015). De promessa a realidade: como o etanol celulósico pode revolucionar a indústria da cana-de-açúcar – uma avaliação do potencial competitivo e sugestões de política pública. *BNDES Setorial, 41,* 237–294.

Naik, S. N., et al. (2010). Production of first and second generation biofuels: A comprehensive review. *Renewable and Sustainable Energy Reviews, 14,* 578–597.

Nyko, D. (2015). Avaliação do potencial competitivo do E2G no Brasil: O Panorama brasileiro e mundial. Available in: https://www.novacana.com/pdf/etanol2G_BNDES.pdf.

Pinto, T. A. (2008). Gasolina, Gás Natural e Etanol: Comparação dos principais impactos ambientais da produção ao consumo final. Universidade Estadual Paulista "Júlio de Mesquita Filho".

Poet-DSM. (2017). Project Liberty. Available in: http://poet-dsm.com/liberty.

Raízen. (2017). Etanol de segunda geração. Available in: https://www.raizen.com.br/energia-do-futuro-tecnologia-em-energia-renovavel/etanol-de-segunda-geracao.

Sticklen, M. B. (2008). Plant genetic engineering for biofuel production: Towards affordable cellulosic ethanol. *Nature Reviews, 9,* 433–443.

UNICA (União da Indústria de cana-de-açúcar). (2016). Indústria química avança em tecnologias enzimáticas para produção de etanol 2G. Available in: http://www.unica.com.br/noticia/3102159920315624493/industria-quimica-avanca-em-tecnologias-enzimaticas-para-producao-de-etanol-2g/.

Conditional Risk and Return in Investment Valuation: An Application to Enrolling in a Higher Education Degree Decision

F. A. Nascimento and E. P. Ribeiro

Abstract The decision to pursue a tertiary education degree can be seen as an investment decision. The decision involves taking up or not a student loan to pay for the higher education degree. This investment decision can be evaluated in a standard net present worth/internal rate of return (IRR) analysis. With uncertain outcomes the net present worth analysis is generally evaluated in a mean (or most likely) scenario, complemented with a sensitivity or risk analysis. We apply a quantile regression technique to provide a simple but powerful analysis of risk-return investment decisions, using the case of student loans in Brazil (FIES) as an illustration. While mean net present worth/IRR for paying for higher education degree with a student loan is positive, the IRR differ by a factor of 30 between high and low wage university degrees wage earners and some women and non-white degree holders.

Keywords Higher education · Investment analysis · Quantile regression

1 Introduction

The decision to take a university degree may be seen as an investment decision, since the classical treatment in the economics literature by Becker (1964). It involves evaluating the trade-off between continuing in the labor market with a high school diploma or pursuing a higher education degree, with the associated costs (tuition and fees, direct costs such as books and materials, and foregone earnings if

F. A. Nascimento
Instituto de Economia, Universidade Federal do Rio de Janeiro,
Av. Pasteur 250, Rio de Janeiro, RJ, Brazil
e-mail: felipe3000nasc@yahoo.com.br

E. P. Ribeiro (✉)
CNPq Researcher and Instituto de Economia, Universidade Federal
do Rio de Janeiro, Av. Pasteur 250, sl.119, Rio de Janeiro, RJ, Brazil
e-mail: eribeiro@ie.ufrj.br

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one does not work while enrolled at the University). The popular press highlight the financial reward analysis when deciding to go to college (Giordano 2016) at the same time that there are questions whether such investments pay off, at least in the US (Economist 2014).

The evaluation of this investment decision can be done in a standard net present worth, or net present value (NPV) analysis. The NPV analysis requires setting up a stream of future of earnings from the investment decision, net of future costs from the financing of the investment (a cash flow), discounted at an appropriate rate (see e.g., Fraser and Jewkins 2013). Dealing with uncertainty in the stream of future earnings includes different strategies, such as considering most likely, optimistic and pessimistic scenarios, or statistical analysis on expected results and volatility using simulation (see e.g., Drury 2003). Monte Carlo simulation requires the knowledge of cash flow distributions that are usually unknown, even if past investment data is available. An additional difficulty is to isolate the effect of different outcome characteristics in preparing the simulation.

We use quantile regression (Koenker 2005) an econometric technique, to deal with uncertainty in investment outcomes and the variability of NPV results. Quantile regression allows the estimation of conditional densities semiparametrically and provide simple, operational estimates of median based expected outcomes and risks involved by looking at different quantiles of the outcome distribution, such as the lower and upper deciles (10 and 90% quantiles). The use of quantile regression to evaluate risk and return in investment decision, in a non-net present value set up is seen in Pereira and Martins (2002). An expected outcome analysis with a risk analysis based on regression standard deviation is seen in Campos et al. (2006). Using standard deviation to model risk in a conditional distribution setup imposes strong assumptions on the conditional variance (such as homoskedasticity), that are avoided using the quantile regression semiparametric technique (e.g., Alexander 2008 or the discussion in Calfa et al. 2015 in finance and operational research).

A regression analysis is suggested to evaluate the conditional distribution of labor market earnings as it is well documented that labor earnings depend on the level of schooling (such as a higher education degree), and also age, experience and non-productive characteristics, such as gender and color. A regression analysis framework allows one to easily incorporate the effect of these characteristics in a simulation analysis.

Our application deals with the decision to take a student loan to finance (private, tuition funded) higher education in Brazil. Since 2010, the government of Brazil set up a large student loan scheme, FIES, to finance higher education. It is a USD6 billion program (2016 data with a USD1 = BRL3 exchange rate), where students can finance their tuition costs fully or partially on subsidized (below market) interest rates.

Higher education investment can be extremely risky, as average monthly earnings for a higher education degree holder in 2013 were BRL3271.26 with a standard deviation of BRL2615.22. For women the average earnings were BRL2708.30 with a standard deviation nearly equal at BRL2202.75 (based on IBGE PNAD

Household survey micro data, the main annual representative survey from the National Statistical Office in Brazil). It is not known whether the investment decision in human capital pays off, i.e., whether the additional earnings from a college degree would cover the financial cost of the student loan and/or foregone earnings.

2 Methods

We model the investment decision using the well known net present worth, or net present value formula, discounting future income streams (FC_t), net of investment costs (I_0), to a present value using a benchmark discount rate. For ease of comparison of results with other investment decision, we present results for a internal rate of return, that is the discount rate that breaks even the investment decision, as seen in Eq. 1.

$$VPL = -I_0 + \sum_{t=1}^{n} \frac{FC_t}{(1 + TIR)^t} = 0 \tag{1}$$

For the case of investment in higher education, the future flow FC_t is taken as yearly earnings, calculated by expanding expected monthly earnings by the so called 13th wage (*Décimo terceiro salário*) and vacation benefits. The I_0 initial investment cost include the present value of financing the cost of a higher education degree over five years, direct costs, such as books transportation and materials, and foregone earnings, when a university student with a high school diploma does not work while enrolled in higher education. Information on tuition was obtained from Hoper, the most important higher education consulting firm. We consider three alternatives (a mid scenario of BRL 654.05, and an upper and lower rate of BRL956.46 and BRL442.68 respectively). We consider a 23 year work life after receiving a college degree to match the average retirement age. Last, two situations are entertained, one in which a student does not work while is taking the higher education degree and one where the student works and take classes in the evening. The latter case is most frequent. The latter case does not include foregone earnings during course work.

The estimates assume financing higher education either through saved income or donations, or paying through a loan. The National Student Loan program in Brazil, FIES interest rates are below market rate and conditions include a grace period after graduation and a fixed term for payment based on course length (see Brasil 2016). For simulating age-earnings trajectories over time based on a cross-sectional information we use real (inflation discounted) interest rates. The real interest rate for 2013 was 1.9%a.a., while net inflation federal bonds rate was estimated at 4.7%a.a. Market rates are higher. For example, car loans, that have lowest rates on personal credit as the vehicle acts as collateral, reach more than 15%a.a.

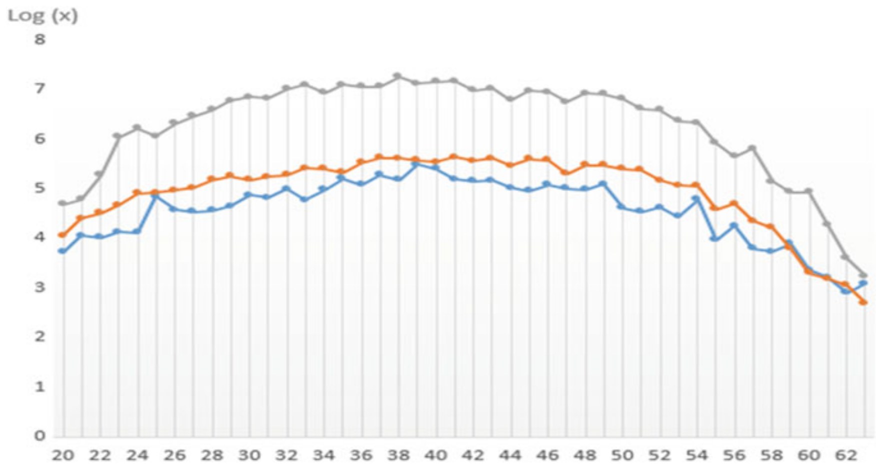

Fig. 1 Average log labor market earnings (x) across age and by schooling levels Brazil, 2013. -•- Higher education; -•- High school education; -•- Basic education; Authors' calculations based on PNAD data

Future earnings were estimated using quantile regression technique for data on a representative survey of all households in Brazil (PNAD), carried out by IBGE, the national statistical office. We use 2013 data, before recession hit Brazil and when FIES outlays reached its peak. We consider higher school diploma holders and higher education degree holders. The sample includes more than 73 thousand observations (Fig. 1).

A so called mincerian equation was run on monthly hourly earnings, standardized for a 40 h work week (w), the Brazilian workweek mode. The functional form follows the literature, such as Ehrenberg and Smith (2001). We use a set of dummy variables for gender (1 if female), color (1 if declared white skin), years of schooling beyond high school (omitted category 11 yrs, i.e., high school) and completed Technical (2 year college) and Superior (4 year university) degrees.

$$\begin{aligned}\ln(w_i) = \beta_0 + \beta_2\, age_i + \beta_3 (age_i)^2 + \beta_4\, gender_i + \beta_5\, white_i \\ + \beta_6 D(12\, yrs)_i + \beta_7 D(13\, yrs)_i + \beta_8 D(14\, yrs)_i \\ + \beta_9 D(15\, yrs)_i + \beta_{10}\, Tec_i + \beta_{11}\, Sup_i + \varepsilon_i\end{aligned} \tag{2}$$

Quantile regression is a regression technique, presented in Koenker (2005), that fits a regression model minimizing a weighted average of absolute value residuals, with weights depending on the quantile of interest. For the median, positive and negative value absolute value residuals are weighted equally. For the 10% quantile, e.g., the negative residuals are weighted by 0.90 and the positive resituals by 0.10, so to 'shift' the regression line down the data mass. Estimation algorithms use linear programming (we use the Stata software for the estimates below). Estimates are consistent and asymptotically Normal under weak assumptions. What is more interesting here, as detailed in Koenker (2005), the predicted values are consistent to transformations such as exponential (recall that $E(\ln X) \neq \ln(E(X))$, but $median(\ln(X)) = \ln(median(X))$) and incorporate heteroscedasticity and random coefficients directly in the model estimates, contrary to least squares that require the modelling of arbitrary heteroscedasticity functional form. In addition, quantile regression estimates can reveal asymmetries in the conditional distribution.

Model estimates are used to predict a (conditional) trajectory for earnings over the working life of a university degree holder, compared to a high school diploma holder, for different social groups (women/men; white/non-white) and thus create the simulated FC_t.

3 Results

Table 1 present the quantile regression estimates for the 'base wage' case (mean, based on least squares) and the 'high wage' (90% percentile) and 'low wage' (10% percentile).

We see that the coefficients are significant and increase as the quantile of the conditional distribution increases, suggesting strong variable conditional variance

Table 1 Coefficient estimates of the effect of schooling on labor market earnings (Eq. 2), for average effect, 10% quantile and 90% quantile

Variable	Least squares	10% quantile	90% quantile	90–10% quantile coefficient diff.
Constant	1.0122	0.8520	1.1062	0.2542
12 years of Sch.	0.1639	0.1010	0.2370	0.1360
13 years of Sch.	0.3485	0.2231	0.4369	0.2138
14 years of Sch.	0.3961	0.2363	0.4981	0.2618
15 years of Sch.	0.3394	0.1205	0.5426	0.4222
Sup—4 year	0.4703	0.4131	0.3975	0.0156
Tec—2 year	0.2194	0.1420	0.1769	0.0349
Age	0.0415	0.0217	0.0689	0.0471
Age 2	−0.0003	−0.0002	−0.0006	0.0003
Female	−0.2778	−0.1520	−0.3311	0.1791
White	0.1781	0.1356	0.1981	0.0625
R2/Pseudo R2	0.2666	0.0769	0.1805	-x-

Brazil, 2013, based on raw PNAD microdata. All coefficients are statistically significant with a p-value less than 0.01

in the earnings across age and schooling and observable characteristics. Considering only foregone earnings as the cost for higher education degree, the *Sup* and the 15 years of schooling dummy (*15 years*) variables coefficients can be interpreted as an (internal) rate of return of taking up a four year university degree compared to maintaining a higher education degree (Ehrenberg and Smith 2001). There is significant variation in the estimates suggest high risk in the investment decision. The average return is 125% [or exp(0.4703 + 0.3394) − 1] (a university degree would double earnings compared to a high school degree holder), but the return can decrease to 70% for low wage earners. For high degree earners the return can reach 156%. Note that the effect of moving up the wage distribution on this simple rate of returns is *asymmetric*.

The above estimates are used to construct simulated earnings trajectories over time for different social groups (males/females, white/non-white). The predicted earnings are offset by the direct costs of attending a university (such as tuition) and the indirect costs (foregone earnings). The *what if* earnings of a university degree holder can be estimated using the model above, keeping all other observable characteristics constant (by considering the years of schooling and the Tec and Sup dummies equal to zero). A large number of possibilities may be entertained for the simulation. We present a baseline case due to space restrictions. Additional estimates are available with the authors upon request. The baseline case considers a white person in the following cases: in a high tuition course and a low tuition course; with no financing (using savings or donations to pay for tuition) and with 100% FIES financing; and working or not working during the university degree.

We see from Table 2 that rates of return vary significantly across cells. They are smaller for women. While tuition in the high tuition case is more than twice the low tuition case, internal rates of return differ by much less. Recall that the tuition applies only to relatively small time frame (college years), compared to the assumed worklife. FIES financing appears as a very interesting decision to increase rates of returns, given the possibility to defer tuition costs to later in the working life. It doubles or trebles IRRs. Working during the course work also increases rate of return, as foregone earnings are not a cost in this case. The simulation has not considered possible lower quality of education or learning in the case of working and taking classes in the evening. A simple adjustment would be to consider the high wage-working cases quite rare.

The most striking feature of the simulations are the differences across the wage distribution. The IRR may increase by almost 10 fold comparing a high wage earner and a low wage earner all else constant. This highlight the need to consider the risks involved in investing in human capital, risks that would be obscured by the expected (mean) results alone.

Last but not least, considering a real interest rate (opportunity cost) of the Brazilian Federal Funds at 4.7%, investing in higher education is barely a positive investment for female low wage earners. If one considers that for non-whites returns are 2–3p.p. lower, the internal rate of return net of opportunity costs may be negative for this doubly discriminated social group.

Table 2 Internal rate of return for investment decision in higher education

			Male			Female		
			10% quantile earnings (%)	Mean earnings (%)	90% quantile earnings (%)	10% quantile earnings (%)	Mean earnings (%)	90% quantile earnings (%)
High Tuition	No Financing	Working	11.3	32.1	77.2	9.7	25.5	57.6
		Not Working	5.8	13.9	23.8	5.0	12.6	22.0
	100% FIES	Working	39.1	140.3	368.1	30.4	106.7	268.2
		Not Working	6.7	17.0	27.6	5.7	16.0	26.5
Low Tuition	No Financing	Working	19.1	52.3	131.0	16.7	41.5	97.4
		Not Working	7.8	62.0	26.4	7.1	15.5	25.1
	100% FIES	Working	45.7	142.8	375.1	38.7	109.1	273.5
		Not Working	8.7	18.0	28.4	8.0	17.2	27.6

Personal returns. Based on coefficient estimates from Table 1. Rates of return are annual

4 Concluding Comments

In this paper we applied the regression quantile technique (Koenker 2005) to an investment valuation problem. The technique is a simple and direct way to incorporate risk in simulations of present value investment analysis, when regression techniques provide support for estimating conditional trajectories of earnings (or costs), and has received very little attention.

We applied this technique to the higher education investment decision, also known as the tertiary education human capital problem for the case of Brazil. Brazil is an interesting case as it is expanding its higher education population rapidly, and has expanded its student loan financial support known as FIES significantly. The fiscal burden of FIES imposed adjustments, but it remains to be seen whether taking up the loans are a good—or too good—investment opportunity.

Our results indicate that investing in higher education may indeed generate positive returns, above the opportunity cost of federal funds (Selic), but with considerable risk involved. Significant dispersion observed in university degree holders generate rates of return from 6%a.a. to 375%a.a. depending on tuition and on financing method. IRRs are lower for women and non-whites. For those workers with lower wages IRRs are below benchmarks for discount rates. Given the social costs of setting up the student loan system and the wide labor market inequalities on observable characteristics the results suggest a possible public policy targeting the possibly discriminated social groups to improve financial dimension of higher education investment.

References

Alexander, C. (2008). *Practical financial econometrics*. Market risk analysis (Vol. II). New York: Wiley.

Becker, G. (1964). *Human capital*. New York: NBER.

BRASIL. Ministério da Educação. Fundo de Financiamento ao Estudante do Ensino Superior. Brasília, DF. http://sisfiesportal.mec.gov.br. Acess: 26 de jun. 2016.

Calfa, B. A., Agarwal, A., Bury, S. J., Wassick, J. M., & Grossmann, I. E. (2015). Data-driven simulation and optimization approaches to incorporate production variability in sales and operations planning. *Industrial and Engineering Chemistry Research, 54*(29), 7261–7272.

Campos, P. T. C., Ribeiro, E. P., & Florissi, S. (2006). Investimentos em capital humano no Brasil: um estudo sobre os retornos financeiros privados de cursos de graduação. *Análise Econômica, 16*(1), 23–46.

Drury, C. (2003). *Management and cost accounting*. London: Thomson Learning.

Ehrenberg, R., & Smith, R. (2001). *Modern labor economics*. New York: Prentice Hall.

Fraser, N. M., & Jewkins, E. (2013). *Engineering economics: Financial decision making for engineers* (5th ed.). Toronto: Pearson Canada.

Giordano, C. (2016). Is investing in a college degree worth it? UsNews & World Report Nov, 14, 2016. http://money.usnews.com/investing/articles/2016-11-14/is-investing-in-a-college-degree-worth-it.

Koenker, R. (2005). Quantile regression. Econometric Society monographs. CUP, Cambridge.

Pereira, P., & Martins, P. (2002). Is there a return-risk link in education? *Economics Letters, 75,* 31–37.

The Economist. (2014). Is college worth it? *The Economist*, April 5, 2014.

A Deterministic Equivalent Problem to Study the Effects of Security Policies

H. Moya and G. Rueda

Abstract A Deterministic Equivalent Problem (DEP) is developed to understand the assignment of threats to secondary inspection at a U.S.-Mexican border port of entry, and how the overall assignment can affect security and the overall reward of further inspection. The United States and bordering countries benefit from the North American Free Trade Agreement (NAFTA). But amongst the positive effects of NAFTA there is a looming drug threat that effects the overall flow of companies supply chains. In 2011, Customs and Border Protection (CBP) processed over 64,000 trucks, rail, and sea containers a day. During that 2011 Fiscal year CBP seized 5 million lb of narcotics, including nearly 370,000 lb at the ports of entry. The objective of the developed DEP is to incorporate real time data and to quantify how security officials assign threats to secondary inspection. This information can provide insight into staffing, resource allocation, and the disruption of industrial supply chains. This study will focus on the Pharr–Reynosa International Port of Entry. The expected outcome of the DEP will provide security officials insight into security policies and the associated cost associated with those strategies.

Keywords Deterministic equivalent program · Operation research
National security · Search theory

1 Introduction

This paper focuses on quantifying the effects of assigning individual threats to secondary inspection during primary inspection. To study these effects a Deterministic Equivalent Problem (DEP) is developed to quantify decisions based

H. Moya (✉)
Department of Manufacturing and Industrial Engineering,
The University of Texas Rio Grande, Edinburg, TX, USA
e-mail: Hiram.Moya@utrgv.edu

G. Rueda
San Antonio, TX, USA

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on the reward of intercepting illegal contraband. The Department of Homeland Security (DHS) has an important role on our borders to inspect and confiscate any illegal material from entering the United States (U.S.). Trying to safeguard incoming material from our southern and northern industrial partners is a difficult activity to do because threats have unpredictable arrival times and come in all shapes and sizes. Investments of time and money to stop threats from entering the U.S. are significant; the budget for DHS in 2016 was about 60 billion U.S. Dollars (DHS 2016). Researchers have studied alternative machines and security systems to detect illicit cargo from enters the U.S., but the best method of solving a security issue is planning to integrate all systems and include agents who are critical when detecting illicit cargo.

The main focus of this paper is on primary inspection and the arrival of threats within the northbound from Mexico commercial trucking environment. The first line of detecting illicit cargo is within primary inspection at ports of entry. This inspection point uses targeting information from DHS's centers for threat targeting.

The aim of this paper is to study different security policies and see what the overall effect has on the economy and on the flow of traffic. By assigning more trucks to secondary inspection, security officials can validate a high level of security, but a side effect would be increasing the overall time for those trucks to get to their final destination. With an estimated 1.3 billion dollars of goods crossing on a daily basis, for every minute that trucks are waiting to cross it costs the United States economy over 116 million dollars (Nichols et al. 2015). U.S. officials have stated that the area in need of improvement is the area of inspection process (Nichols et al. 2015). Using a DEP is beneficial because it has the ability to incorporate current data and handle a somewhat random arrival rate. A DEP uses realizations based on current statistical analysis of random variables to make a model estimation. Using these realizations for stochastic variables a beginning step is made to establish a stochastic model. Using different scenarios users can then make comparisons and study the effect the random have on the entire system. This can be beneficial to security officials in terms of preparing budgets, staffing, and the requisition of more resources in a given time period.

This paper is organized as follows. Section 2 exposes readers to the importance of the commercial trade across the Rio Grande Valley (RGV) and the threats that effect the area. Section 3, the analysis of data and the explanation of a deterministic equivalent program is presented as a method to analyze threat assignment to secondary inspection. Section 4 presents results obtained from applying the suggested program to different cases that were constructed based on data analysis. Section 5 indicates the future work and its application in today's political environment and a conclusion of the work.

2 Background Information

This section focuses on two major topics, the first being the drug threat in South Texas and the second are methods which academics propose for improving border security. These two-section shed light on the current state of South Texas and how academics are solving the issue of border and national security.

2.1 *Pharr–Reynosa International Port of Entry and the South Texas Drug Threat*

In 2013, total U.S.-Mexico trade amounted to 507 billion dollars. From the total trade amount with Mexico, 66% or 336 billion dollars was transported by truck, 73% of the 336 billion dollars was moved through Texas POEs (Nichols et al. 2015). Government officials have reported that growth will continue for years to come. Since the introduction of NAFTA Mexican relations have accounted for 769 million dollars to the United States every day (Nichols et al. 2015). The Pharr–Reynosa International Bridge has been the seventh busiest port in the United States and the fourth along the U.S. Border with Mexico. In 2015, Pharr–Reynosa has become the 1st port for produce, the 3rd for electrical/industrial, and the 2nd port for the exporting of natural gas (Pharr POE 2015).

One of the major threats in the United States and the Southern border is contraband smuggling. Through contraband smuggling Transnational Criminal Organizations (TCOs) have taken power and control of illegal activities occurring along Southern border communities. TCOs have the ability to span their reach into different illegal activities because of their transnational status, which span across terrorism, human smuggling, and organized crime. Drug users in the United States have spent over 100 billions dollars in 2010 on cocaine, heroin, marijuana, and methamphetamine (BEA 2017). When comparing, the money spent by Americans on drugs in 2010 compared to the manufacturing sector GDP of Texas of the same year which is an estimated 178 billion dollars it is obvious that drugs in the United States is a great threat (DHS 2014). To combat the demand of illegal contraband, the United States has invested over 394 million dollars in technology and infrastructure to handle the ever-changing threat that TCOs pose on U.S. citizens and its economy (DHS 2016).

2.2 *Methods of Improving Border Security*

Government officials have looked into what causes delays during the border crossing process. Their research includes firsthand accounts from brokers, transportation official, and security officials. They have concluded that deficient infrastructure, inadequate staffing, lack of staffing flexibility, and limited hours of operation all contribute to delays during the border crossing process (Nichols et al. 2015). There has been much research to develop solutions to solve these issues that have hampered the border crossing process.

The Department of Homeland security has developed two programs to help secure the commercial supply chain, the Customs Trade Partnership Against Terrorism (C-TPAT) and the Free and Secure Trade (FAST), which are among the most popular programs in the commercial environment. When companies join the C-TPAT program, they agree to work with CBP to safeguard their supply chain, identify security gaps, and implement specific security measures. CBP explains that the FAST program is “a commercial clearance program for known low-risk shipments entering the United States from Canada and Mexico” (DHS 2014).

Moya and Villa (2013) use statistical theory specifically the “Rate of False Positives” within the secondary population as a way to identify a way to track effectiveness of agents/intelligence/procedure. The performance measure involved in the paper was to tally the attempts, and use Rate of False Positives to calculate the effectiveness of the DHS in detecting contraband. Nikolaev et al. introduce a sequential stochastic security design problem (SSSDP) to solve the issue of aviation security. The approach is a two-phase method; the first phase is a deterministic optimization model with purchasing budget and space constraints. The second phase of the model is a stochastic passenger assignment problem to optimize total security decision within a fixed screening period. The objective of the two-phase model is to optimize total security with phase one and two being interdependent of one another decisions. From a numerical example presented in the paper, it was reported the SSSDP enumerated all prohibited items expected to be clear for a given security system scenario (Nikolaev et al. 2007). In a previous paper Rueda and Moya designed a linear program that estimated port secondary inspection methods based on type of threat and resource used (Rueda and Moya 2015). This paper is a continuation of that work in understanding the assignment to secondary and how it would affect the overall port’s resources.

3 Stochastic Modeling and DEP Equivalent

3.1 Weekday Arrival Analysis

The challenges of researching in border/national security is the issue of data. For this research, the data required to implement the proposed programs would require the threat population arrivals associated with the Pharr–Reynosa International Port of Entry. Searching for data revolved around visiting websites of different Departments and Agencies that dealt with criminal organization. These Department and Agencies contain numerous reports on the subject of smuggling illicit material across U.S. borders. But these reports contain data that has been processed to report on the criminal organization they are studying. In all cases the data used was not publicly available and can only be accessed to government law enforcement officers.

The use of Texas Transportation Institute's online commercial monitoring application provided raw arrival data for the Pharr–Reynosa International Bridge. What this study is interested in is the expected threat arrival rate for all arrivals to the Pharr–Reynosa International POE. This application did not collect data on threat arrivals, but records arrivals and departures for the port in question. Using the arrival and departure data an estimated threat population could be assembled based on the comparison of the two data sets. Using this method one can only calculate the potential threat population on a per day basis. DHS defines trucks as a "threat" if "An assessment of a criminal or terrorist presence within a jurisdiction integrated with an assessment of potential targets of that presence and a statement of probability the criminal or terrorist will commit an unlawful act. The assessment focuses on the criminal's or terrorist's opportunity, capability, and willingness to fulfill the threat" (CBP 2008). If these vehicles and their cargo are considered to be a threat; DHS proceeds to classify them as terrorist activity, drug smuggling, hijacking, corruption levels, and human smuggling.

With an estimated daily threat population one can then calculate a per hour arrival rate for each day. The threat population data consisted of 49 weekday data points spanning from the months of April through June. The descriptive statistics stated the average threat arrival rate per day was 710 suspected vehicles, with a standard deviation of 106. The highest daily estimated threat population was 1170 and lowest was 466. Using proportions based on current drug trends we further disseminate the threat population because they are a variety of threats with different characteristics when it comes to security, such as reward for detection, time for inspection, and overall delay time.

No statistical distribution could be fitted to the data with a high level of confidence. One can assume that this only validates the result that threat arrivals/truck arrivals fall within a random arrival rate and would need further collection of data to determine a distribution that would follow these characteristics. Another possible solution in finding a distribution would be to lower the data collection time interval and study smaller segments. For the purpose of this paper the descriptive statistics will provide enough information to make realizations of the threat population for the proposed model.

3.2 Deterministic Equivalent Modeling

A Deterministic Equivalent Problem (DEP) is used to understand how random variable effect the overall system in question. A DEP uses realizations of the random variables in the form of probabilities of occurrence. These realizations need to be tested in the form of scenarios. These scenarios should describe the different possibilities that could occur in a stochastic environment. Essentially a DEP reduces the stochastic problem to a deterministic one, such that users can identify how variables effect the overall system. With the threat of smugglers and terrorists crossing material through commercial POEs a high level of security needs to be implemented to secure the nation from the possibility of an attack by drugs or weapons of war. The overall linear program contains an objective function in the form of a vector and four matrices constrains. The developed program evaluates the decisions for primary inspection and the effects of a growing threat. The end objective of this program is to maximize the reward of detection. By maximizing the reward associated with threats DHS can evaluate the assignment of threats to secondary and see how a threat population effects the overall goal of disrupting the drug trade. The decision variable associate with the model is $\boldsymbol{x_{i,j}}$, which represents the number of trucks categorized as i threat {marijuana, cocaine, heroin, methamphetamine, …, N}, and j threat level {high, medium, low}. Where N is the last type of threat that a possible port experiences within a daily basis. The decision variable is identified as a positive integer value. This DEP only focuses on the drug trade because it has a resounding effect on the nation and the people who live well-beyond the RGV. The benefits of applying such a program is that multiple scenarios can be tested to fine tune the system and reach the goals DHS lays out for national security.

$$MAX : z = \sum_{i}^{N}\sum_{j}^{3} ER_{i,j} * x_{i,j} - \sum_{i}^{N}\sum_{j}^{3} k_{i,j} * x_{i,j} - \sum_{i}^{N}\sum_{j}^{3} T_c * SI_{i,j} * x_{i,j} \tag{1}$$

Subject To:

$$\sum_{j=1}^{3} x_{ij} \le \lambda * \sum_{j=1}^{3} \theta_{i,j}, \quad j = 1, 2, 3 \tag{2}$$

$$\sum_{j=1}^{3} x_{ij} \le \beta * \sum_{j=1}^{3} \theta_{i,j}, \quad i = 1, 2, \ldots, N, \;\; j = 1, 2, 3 \tag{3}$$

$$\sum_{j=1}^{3} x_{ij} \le \lambda * \theta_{i,j}, \quad j = 1, 2, 3 \tag{4}$$

$$x_{ij} \ge 0, \quad i = 1, 2, \ldots, N, \;\; j = 1, 2, 3 \tag{5}$$

3.2.1 Objective Function

As mentioned before, the objective function considers the threat estimated value (which is considered to be the reward), and two different cost associated with the possibility of an infiltration by a threat i.e. (a truck caring a threat i with risk level j) through a POE. The first part of the objective function is the reward matrix where each possible threat type is assigned an average reward if drugs are detected. The average cost of drug threats was gathered based on a 2011 study on a drug assessment of the RGV (DOJ 2011).

The first cost associated with the objective function is the "cost per secondary inspection." A multiplication of the selected $\boldsymbol{x_{i,j}}$ as mentioned before symbolizes the number of threats arriving in a given time interval in this case an hour, multiplied by the expected cost of inspection $\boldsymbol{k_{i,j}}$ and are estimated costs based on the work of Cedillo-Campos et al. (2014). The resulting units for this cost is dollars per inspection.

The second cost associated with the objective function is the expected cost of delaying goods for secondary inspection this is an average cost of 238.42 dollars per h of wait time which encompasses 6 different types of shipments Just-In-Time (JIT), Non-JIT, Perishables, Non-Perishables, Non-Specified, and Empty trailers. This estimate was provided by Texas Transportation Institute (Vadali et al. 2011). The units for the second cost is dollars per truck. A single dollar value is used because arrival data is not categorized as a type of goods but is blindly collected. The average wait time was gathered by Campos et al. who validated results not only on the U.S. side but also used Mexican scholars to study the effects of border security within Mexico.

Each part of the objective function represent reward/costs DHS has to face on a daily basis and needs to consider when dealing with total security. Specifically, when studying the amount of traffic sent to secondary inspection. By considering the reward and costs associated with searching suspected threats the objective function describes different elements that affect the overall security decisions within primary inspection.

3.2.2 Constraints

Equations 2 and 4 ensure that marginal and conditional probabilities match to decide the overall assignment possibilities. These constraints are required to validate the realization of a threat arriving based on the probabilities. In statistical theory, the marginal probabilities deal with subsets of a universal set. The conditional probability deals with the individual probability of an event occurring. When conducting, preliminary testing using only the marginal constraint it would overlook the conditional probabilities that were not valid for a certain combination. For this reason, both the marginal and conditional constraints need to be present for the program to deal with both probabilities. Equation 2 ensures that the subsets probabilities have not been invalid when considering the individual probabilities. The need for Eq. 2 is to ensure that the summation of events will be valid. Equation 2 cannot exceed the estimated summation of the subset of events. Equation 4 ensures that the individual probabilities for all threats combination are assigned accordingly. This is to ensure that the independent event occurs during the time interval. This is the more important constraint because it validates the arrival to the system. But conditional probability would be hard to predict based on predetermined knowledge given to DHS officials. Equations 2 and 4 are check conditions for the overall assignment of the threat probability matrix. As referenced in Feldman and Flores "The situation often arises in which the experimentalist has knowledge regarding one random variable and would like to use that knowledge in predicting the value of the other (unknown) random variable. Such predictions are possible through conditional probability functions" (Feldman and Valdez-Flores 2010). Equations 2 and 4 are forms of a statistical check to ensure the likely hood of that event occurring. These two constraints do not have an overall effect on the objective function but will have an effect on Eq. 3, which will validate the ports capability based on threats arrivals.

Equation 3 is in place to consider the amount of traffic to secondary inspection. The DEP makes the decision on which threats should be sent based on the current threat distributions. Equation 3 summate all threat level populations and assigns according to the allocated space for that threat level in secondary inspection. The ß variable represents 60 inspection lanes but varies between ports with limited space for inspection. The secondary inspection allocation space is associated with the overall forecast threat population estimates. The right-hand side of Eq. 3 is always updating because the resources become free after a certain period of time. In many cases, DHS attempts a 100% security policy by applying such constraints on resources, this program can be applied to prove the effects of such security policy.

4 Case Studies

This section will present 2 scenarios the first is the Base Case that uses the expected mean arrival rate per hour. The second case, will go further and test one standard deviations away from the expected threat arrival rate. The expected threat arrival rate per hour is 47 threats with a standard deviation of 7.11. The optimization program used for all testing is Microsoft Excel 15.28 with the add-in program called Solver.

4.1 Base Case

The expected threat arrival was below the capacity of secondary inspection which is 60 slots, so there would be enough room for inspecting all possible threats in secondary within the first hour of operations. The total assignment for the Base Case indicates that the total population sent to secondary inspection would be 44 trucks. The possible reward for sending 44 trucks to secondary would amount to $83,806,160.74 that is including the cost of inspection and the cost of interfering with trucks processing. Based on optimal conditions, it would not be appropriate to send all 47 suspected trucks to secondary inspection. Based on optimal conditions, each threat subset assigned more than 50% of resources within secondary

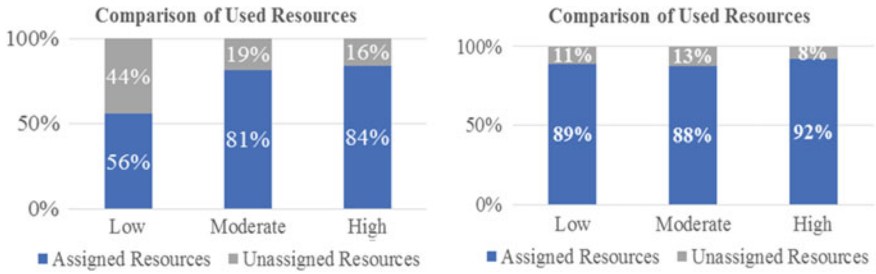

Fig. 1 Left: Resources based on base case optimality. Right: Resources based on one standard deviation optimality

inspection see Fig. 1 for validation. It is also evident by the results that the Pharr–Reynosa International POE still has room for further assignment in the next hour. Lastly, all conditional probability constraints were completed and did not affect the marginal constraints. The take away from this case is that just on the expected amount of threats the Pharr–Reynosa International POE has used more than half of all their resources within secondary inspection. This will essentially hinder the security system in the future, causing agents to prioritize threats that arrive.

4.2 *One Standard Deviation*

The second case tests an arrival rate of 54 threats per hour assignment. This is getting close to the secondary inspection capacity of 60. The results of adding one standard deviation the optimization program found a solution of $83,806,160.74 potential reward for assigning the threat population to secondary inspection. The total assignment of all threats to secondary was 53. This means that based on an optimal condition it was not worth assigning a potential truck carrying heroin with a low risk to secondary inspection. For the secondary resource constraints, there was still room to assign potential threats in the future. The marginal constraints were completed while the conditional threats lacked an assignment of the heroin low risk threat. This choice did not affect the overall program and all conditions were satisfied. The binding variable was marijuana because it not only had the most assignments but also had the highest probabilities of arrival. In this case over 80% of all resources in each threat subset category were being used. This would be a worst-case scenario because there would not be enough resources for the next hour time segment.

5 Conclusion

The take away from this program and the case studies is that there was not enough capacity for the amount of threats estimated to arrive to the Pharr–Reynosa POE. This finding also leads to other problems such as supply chain security and inspection techniques. DHS is aware of the conditions of the supply chain and have been trying to increase the members in their programs to resolve this issue. Security techniques are effected by the space and resources present at the Pharr–Reynosa International POE so an increase in space would elevated this concern. While this study was being made the Pharr–Reynosa has broken ground in increases secondary inspection from 60 lanes to 100 inspections. This agrees with the finds in this report and shows the significance of the presented case studies. Because this paper had a page limit a full explanation of results and analysis could not be present.

References

Bureau of Economic Analysis. (n.d.). Retrieved January 11, 2017, from https://www.bea.gov.

Cedillo-Campos, M. G., Sánchez-Ramírez, C., Vadali, S., Villa, J. C., & Menezes, M. B. (2014). Supply chain dynamics and the “cross-border effect”: The U.S.—Mexican border’s case. *Computers & Industrial Engineering, 72,* 261–273. https://doi.org/10.1016/j.cie.2014.03.015.

Feldman, R. M., & Valdez-Flores, C. (2010). *Applied probability and stochastic processes*. Berlin: Springer.

Kilmer, B., Everingham, S. S., Caulkins, J. P., Midgette, G., Liccardo Pacula, R., Reuter, P. H., & Lundberg, R. (2014). *How big is the U.S. market for illegal drugs?* (pp. 1–4). RAND Corporation.

Moya, H., & Villa, J. (2013). Rate of false positives as a security performance measure. In *Proceedings of the 2014 System Engineering Research Conference*.

Nichols, R., Anchia, R., & Madden, J. (2015, January 12). Joint interim committee to study the effects of border wait times interim report 2014 (Rep.). Retrieved August 12, 2016, from January 12, 2015.

Nikolaev, A. G., Jacobson, S. H., & Mclay, L. A. (2007). A sequential stochastic security system design problem for aviation security. *Transportation Science, 41*(2), 182–194. https://doi.org/10.1287/trsc.1070.0198.

Pharr-Reynosa Intl Bridge. (2015, November/December). Retrieved August 10, 2016, from http://pharr-tx.gov/departments/pharr-reynosa-intl-bridge/.

Rueda, G., & Moya, H. (2015, January). Rate of false positive on specific border cargo detection. In *IIE Annual Conference*. *Proceedings* (p. 1852). Institute of Industrial Engineers-Publisher.

The United States of America, U.S. Customs and Border Protection. (2008). *C-TPAT’s Five step risk assessment process* (pp. 1–39).

United States of America, Department of Justice. (2011). South Texas High Intensity Drug Trafficking Area: Drug Market Analysis 2011.

United States of America, Department of Homeland Security. (2014). U.S. Customs and Border Patrol Performance and Accountability Report Fiscal Year 2014.

United States of America, Department of Homeland Security. (2016). Budget-in-brief 2016.

Vadali, S., Kang, D., & Fierro, K. (2011). Border Delays and Economic Impact to the Freight Sector: An Exploration of the El Paso Ports of Entry.

Electronic Junk: Best Practice of Recycling and Production Forecast Case Study in Brazil

C. A. Albuquerque, C. H. P. Mello, V. C. Paes, P. P. Balestrassi and L. B. Souza

Abstract The concern with the disposal of waste generated by industry as well as by households is not recent. This work has sought to make a review on the production and disposal of the waste generated by electrical and electronic products, such as computers and mobile phones. Also, this review aimed to characterize the components of such waste and investigate the effectiveness of current methods of waste treatment. In addition, a tool is proposed to predict the production of computers in Brazil through the statistical method of autoregressive integrated moving average (ARIMA) models, which suggested the model ARIMA (0, 0, 1) to carry out the forecast. With this model, it was possible to suggest that the production of computers in Brazil, due to the global economic crisis, should continue to decrease.

Keywords Electronic junk · Recycling · E-waste

1 Introduction

The concern with environmental degradation is not recent. There are records of not sustainable use of natural resources since two million of years B.C. and the harmful effects, as the salinization process of the soil of Sumria civilization that caused its disappearance (Monjeau and Smith-Flueck 2013).

Concerns with the scale of exploitation of natural resources, which in recent decades has increased exponentially, and also with the fate of residues, that are generated each time in larger quantities, been cited as potential threats to the

C. A. Albuquerque
Industrial Engineering Institute, Federal Institute of Education, Science and Tecnology of South of Minas Gerais—IFSULDEMINAS, Av. Maria da Conceição Santos 900, Bairro Parque Real, Minas Gerais, Brazil

C. H. P. Mello · V. C. Paes · P. P. Balestrassi (✉) · L. B. Souza
Industrial Engineering and Management Institute, Federal University of Itajubá—UNIFEI, Av. BPS 1303, Pinheirinho, Minas Gerais, Brazil
e-mail: ppbalestrassi@gmail.com

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survival of human beings (Coelho et al. 2013; Santagata et al. 2017). So, currently there is a very large effort in relation to the sustainability of our society, causing the development of products that are environmentally friendly. In 2010 the Tenth UNEP-Convention on Biological Diversity developed a resolution that enlarged the land conservation area, from 10 to 17% (Moilanen 2012). Currently, some countries require that new products meet environmental requirements before they are approved and placed on the market (Askham et al. 2012).

A type of waste that deserves attention of society and the scientific community is the residue generated by electrical and electronic products (Borthakur and Govind 2017). This type of waste was named e-waste or waste of electrical and electronic equipment (WEEE) by the European Union Directive 2002/96/EC (European Parliament, 2002) and it is defined as any residue composed of any part of the equipment mentioned in the directive 2002/96/EC (Li et al. 2013). In other words, the wastes are those unused or obsolete electronic devices (Man et al. 2013). This concern whether is due to, among other reasons, to the fact that this type of waste is increasing worldwide, particularly in industrialized countries, such as USA, European countries and South Korea (Jha et al. 2012).

Another reason that contributes to the concern with the e-waste is the degradation of the environment: by the high consumption of related products, whose production consumes many natural resources and contains hazardous materials; so, their destination after use becomes a key concern (Garlapati 2016). Thus, countries have introduced laws that seek to improve recycling methods so that the level of reuse is as high as possible (Cui and Forssberg 2003), since after the use of these products, another factor that may lead to the degradation of the environment is the inappropriate disposal of them, mainly because of its composition, with elements that are very harmful to people and also to the environment (Garlapati 2016). Recycling e-waste material, with inadequate techniques, can cause the release of heavy metals and pollutants that can cause biomagnifcation and this is very detrimental to human health (Man et al. 2013). Considering this risk, some developed countries seek to solve their problems with this type of waste by exporting or donating used or obsolete electrical and electronic equipment to developing countries. However, many nations, which received these donations, worried about their own environment and the well-being of their population, have been exercising greater control over these activities. In January 2011, China implemented legislation that mandates producers of electrical and electronic equipment for the collection and destination of post-use products and also disciplines e-waste exports to both China and Hong Kong (Man et al. 2013).

Technology and the use of software have proved to be a useful tool in decision-making related to problems affecting the environment (Sarkar and Illoldirange 2010). Faru (2010) developed a hybrid neural network and ARIMA model for predicting time series of water quality. Such tools can also be useful in forecasting products that will generate e-waste, such as computers, and, consequently, assist in the planning of waste disposal. Therefore, in addition to carrying out a review in the literature on the destination of waste, mainly the electronic products, it is also the objective of this work to develop a forecast model for the production of computers in Brazil using autoregressive integrated moving average (ARIMA) models.

2 Literature Review

2.1 The Electronic Waste

New technological products are launched almost every day, especially products linked to the information industry, such as computers and cell phones (Rahmani et al. 2014). The reason for this increase is due to the great technological advance, especially in the areas of electro-electronic equipment (Jha et al. 2012); and the reduction of the acquisition prices of these products (Tanskanen 2013). It is estimated that between 20 and 50 million tons of these wastes are generated annually (Song and Li 2015). And every time a new product is launched, consumers, especially the younger ones, tend to buy the new product without verifying the real need to make such a purchase. As stated by Borthakur and Govind (2017), the rapid advance in technology and strong incentives for consumption bring a drastically reduced lifespan of products, rising quantity of e-waste. A direct consequence of this habit is the increase in e-waste.

The annual production of computers in Brazil has been increasing and consequently the generation of waste increases. In North America, in 2005, the obsolete personal computers produced an average of 806,700 tons of e-waste; in the European Union it averaged 594,600 tons (Li et al. 2013). Developing countries are also producing increasing amounts of e-waste, such as China which produced around 2.5 million tons in 2005 (Li et al. 2013); and because of its increasing production rate, is becoming a leader in waste storage (Song and Li 2015). This increment in the e-waste is also perceived in Brazil.

But the most alarming fact is that although products that generate e-waste are heavily present in modern society (Zhang et al. 2012), currently there is no correct destination for them. According to Simes and Catapreta (2013), landfills remain an essential part of waste management systems and in many countries they are the only economic way for waste disposal; thus contributing to increase environmental degradation and also could endanger the health of the population (Song and Li 2015), because the e-waste contain toxic products such as mercury, cadmium and lead, which are therefore classified as hazardous waste by the Basel Convention (Li et al. 2013). Which was adopted on 22 March 1989 and put into effect on 5 May 1992 and deals with the regulation of the export of hazardous waste (Man et al. 2013). Among the components of the e-waste, it is worth mentioning the printed circuit board (PCB) (Hadi et al. 2013). The PCB is a major component in all electrical and electronic equipment (Tanskanen 2013), and consequently, it is employed in all such equipment (Jha et al. 2012), and is generally discarded to the landfill or incinerated (Hadi et al. 2013).

2.2 Allocation of WEEE

The ways in which countries treat their electrical and electronic waste is a matter of concern to the entire international community (Man et al. 2013). Some segments seek to reuse the largest possible percentage of waste, not only for ecological reasons, but also for economic reasons such as the recovery of valuable materials (Cui and Forssberg 2003). Purely economic motivation, without due care for the ecological issue, can increase the risks to the environment and also the workers involved in the recycling activity (Schnoor 2012). This can be observed in China, where considerable part of the recycling process is done in unspecified places and often by informal and even clandestine sectors (Song and Li 2015).

Despite the risks to both the environment and the population, there are still countries that receive WEEE, such as Ghana, South Africa and the Philippines, and do not seem to have an effective recycling program for this type of waste (Li et al. 2013). They receive waste from developed countries, especially the USA, which despite being one of the largest producers of WEEE, have not yet ratified the Basel Convention (Man et al. 2013). The destination of WEEE should not be in landfills. This can lead to the diffusion of the hazardous elements mentioned to the soil, degrading the environment and placing the health of the local population at risk. For example, a printed circuit board may contain, on average, 20.13% Cu, 3.59% Al, 2.78% Zn, 2.10% Pb, 3.27% Sn, (Jha et al. 2012) and if discarded in landfills, could contaminate the soil and water in the region.

2.3 The Recycling of WEEE

Despite electronics being formed by different types of materials such as glass, plastic and metals, the goal of this work is to investigate the recycling of components such as electronic and printed circuit, because these products contains harmful components to the environment, such as heavy metals, especially lead (Jha et al. 2012).

An important step in the recycling of WEEE is the identification and characterization of the waste components, in order to identify valuable materials, and especially hazardous (Cui and Forssberg 2003). After this characterization, the material can be grinded or crushed and then the various materials that make up such parts can be separated. The separation can be done by physical methods, such as magnetic separation or density difference, or by chemical processes, such as dissolution in acid. A method of making the physical separation of the materials that make up the metal part of these wastes is to use a pyro-metallurgical process (Jha et al. 2012), also known as high temperature metal recovery (Schweers et al. 1990). To reuse metals such as copper in cables and wires of electrical and electronic products, it is common to burn these materials to eliminate the plastic part and thus reuse the metal (Man et al. 2013). However pyro-metallurgical processes, in addition to having a high cost, can increase environmental degradation by releasing toxic products and carcinogenic compounds into the air (Jha et al. 2012). An alternative to the pyro-metallurgical process, which is less costly financially and ecologically, is the chemical separation, such as the hydro metallurgical method, which is a method based on the solubilization of metals (Jha et al. 2012). Also the extraction of metals with acid and the cutting of the surrounding plastic to reuse the metal part seem to be better and less toxic alternatives than the pyro-metallurgical methods (Man et al. 2013). When the objective, besides environmental, is also economic, such as recovery of rare or high-cost materials, the WEEE recycling method must take into account the characterization of the components that form such waste (Cui and Forssberg 2003).

3 Production Forecast Model

The use of time series forecasting, which consists of the development of a mathematical prediction model, based on observations of historical data, can be a powerful tool in several areas (Khashei and Bijari 2011; Khashei et al. 2012). When the data is complex to be modeled using a linear form, the ARIMA method is more suitable for the creation of a mathematical model (Faru 2010). Thus, this work has chosen to use the ARIMA model to make predictions of computer production, which is a widely used model for time series (Faru 2010; HO et al. 2002); that is obtained with stochastic or deterministic process and can be represented through mathematical modeling. The first step is to build a graph with the historical data of computer production in Brazil as shown in Fig. 1. Visually it is not possible to

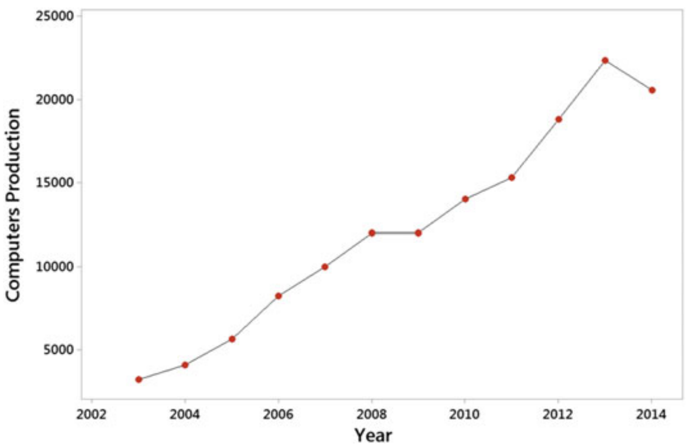

Fig. 1 Computer production in Brazil

identify any cycle in the graph formed by such data. Also, visually, it looks like the chart indicates an upward trend.

In order for the ARIMA model to be applied satisfactorily, the time series object of study must be a stationary series, that is, a series that shows neither trend nor seasonality. One way to model a time series that meets these conditions and get a satisfactory fit is to use tools that develop models whose white noise residues are randomly identically distributed. Models whose residues are not white noise, are models that tend to be autocorrelated and, therefore, predictions made by these models have little accuracy.

The autocorrelation function (ACF) for the production of computers in Brazil values fall from 0.77 to practically zero and follow a sine pattern around zero. This pattern of ACF is typical of stationary time series.

Both the ACF and the Partial Auto Correlation Function (PACF) do not show significant autocorrelation except for lag one. So, both functions suggest that there is no significant trend for this time series. Thus, both the ACF and the PACF suggest the value zero for the parameter d of the ARIMA model (p, d, q), where d means how many times the series will be differentiated to make the series stationary.

Analyzing the ACF it is also possible to verify an exponential drop in the autocorrelation values. The fact of exponential fall suggests that the model that best represents this series is the autoregressive (AR) model. This is confirmed by the PACF, where there is only a significant partial autocorrelation for lag 1, thus suggesting the AR (1) model.

Analyzing the ACF and PACF functions for the residues, it was possible to observe that there is no significant correlation nor any pattern suggesting that the AR (1) model is adequate.

The time series obtained from real data are rarely stationary, also the absolute majority has some seasonal component. Although the analysis done with indicates that the best model for this series is AR (1), other models were also evaluated.

Because the parameter d is estimated as zero, the ARIMA models investigated were of the ARIMA type (p, 0, q). Among the models whose parameter d = 0, the ARIMA model (0, 0, 1) was the best performing, suggesting the moving average MA model (1), according to the analysis done with the MINITAB software, shown in Table 1.

Considering these results, a mathematical modeling was performed to predict the production of computers in Brazil, using the ARIMA model (0, 0, 1). Through the

Table 1 Final parameters estimates

Type	Coef.	Coef. EP	T	P
MM 1	−0.8664	0.2406	−3.60	0.05
Constant	12.180	1896	6.42	0000
Average	12.180	1896	–	–

results it is possible to suggest that the production of computers in Brazil should decline, as already observed in the year 2014, stabilizing around a production of 12.2 million units per year.

4 Conclusion

With the advancements in technology and the ease of acquiring electro and electronic products, the amount of e-waste is increasing worldwide. Despite this increase, much of the e-waste still lacks adequate treatment. Even some recycling practices, such as the reuse of metals through pyro-metallurgical methods, serve much more economic than environmental issues, as they end up contaminating the environment. For these reasons, a deeper investigation to develop e-waste recycling techniques are needed, so that the main objectives are more ecological than purely economic; this kind of research deserve attention of the academic community and it is proposed as future work, investigating mainly the reutilization of e-waste in new products. The use of software with mathematical and statistical methods capabilities are a valuable tool in the prediction of waste production and can provide valuable information for planning the treatment.

This work investigated the use of the ARIMA method to predict the production of computers in Brazil. The ARIMA model (0, 0, 1) is suggested due to the fact that the model presents p-value = 0.005, therefore smaller than 0.05, confirming that the model has a good reliability. As it is reasonable to establish a relationship of proportionality between the production of a product and the generation of waste generated by it, such a model can contribute to the planning of the treatment of future waste generated by the computers produced in Brazil.

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References

Askham, C., Gade, A. L., & Hanssen, O. J. (2012). Combining REACH, environmental and economic performance indicators for strategic sustainable product development. *Journal of Cleaner Production, 35,* 71–78.

Borthakur, A., & Govind, M. (2017). Emerging trends in consumers' E-waste disposal behaviour and awareness: A worldwide overview with special focus on India. *Resources, Conservation and Recycling, 117,* 102–113.

Coelho, M. S., Resende, F. M., & Fernandes, G. W. (2013). Chinese economic growth: Implications for Brazilian conservation policies. *Natureza e Conservacao, 11,* 88–91.

Cui, J., & Forssberg, E. (2003). Mechanical recycling of waste electric and electronic equipment: A review. *Journal of Hazardous Materials, 99,* 243–263.

Faru, O. D. (2010). A hybrid neural network and Arima model for water quality time series prediction. *Engineering Applications of Artificial Intelligence, 23,* 586594.

Garlapati, V. K. (2016). E-waste in india and developed countries: Management, recycling, business and biotechnological initiatives. *Renewable and Sustainable Energy Rev., 54,* 874–881.

Hadi, P., Barford, J., & McKay, G. (2013). Toxic heavy metal capture using a novel electronic waste-based material-mechanism, modeling and comparison. *Environmental Science and Technology, 47,* 8248–8255. PMID: 23837660.

Ho, S., Xie, M., & Goh, T. (2002). A comparative study of neural network and box-jenkins Arima modeling in time series prediction. *Computers & Industrial Engineering, 42,* 371375.

Jha, M. K., Kumari, A., Choubey, P. K., Lee, J. C., Kumar, V., & Jeong, J. (2012). Leaching of lead from solder material of waste printed circuit boards (PCBs). *Hydrometallurgy, 121,* 28–34.

Khashei, M., & Bijari, M. (2011). A novel hybridization of artificial neural networks and {ARIMA} models for time series forecasting. *Applied Soft Computing*, *11,* 2664–2675. The Impact of Soft Computing for the Progress of Artificial Intelligence.

Khashei, M., Bijari, M., & Ardali, G. A. R. (2012). Hybridization of autoregressive integrated moving average (ARIMA) with probabilistic neural networks (PNNs). *Computers & Industrial Engineering, 63*(1), 37–45.

Li, J., Liu, L., Zhao, N., Yu, K., & Zheng, L. (2013). Regional or global WEEE recycling. Where to go? *Waste Management, 33*(4), 923–934.

Man, M., Naidu, R., & Wong, M. H. (2013). Persistent toxic substances released from uncontrolled e-waste recycling and actions for the future. *Science of the Total Environment, 463,* 1133–1137.

Moilanen, A. (2012). Spatial conservation prioritization in data-poor areas of the world. *Natureza & Conservacao, 10,* 1219.

Monjeau, A., & Smith-Flueck, J. A. (2013). The need to unmask lurking false friends: Sustainability is a state, not a process! *Natureza & Conservacao, 11,* 9698.

Rahmani, M., Nabizadeh, R., Yaghmaeian, K., Mahvi, A. H., & Yune, M. (2014). Estimation of waste from computers and mobile phones in iran. *Resources, Conservation and Recycling, 87,* 21–29.

Santagata, R., Ripa, M., & Ulgiati, S. (2017). An environmental assessment of electricity production from slaughterhouse residues. Linking urban, industrial and waste management systems. *Applied Energy, 186,* 175–188.

Sarkar, S., & Illoldirange, P. (2010). Systematic conservation planning: An updated protocol. *Natureza & Conservao, 8,* 1926.

Schnoor, J. L. (2012). *Extended producer responsibility for e-waste. Environment science and technology*. Washington, DC, USA: ACS Publications.

Schweers, M. E., Onuska, J. C., & Hanewald, R. H. (1990). A pyrometallurgical process for recycling cadmium containing batteries 03.

Simes, G. F., & Catapreta, C. A. A. (2013). Monitoring and modeling of long-term settlements of an experimental landfill in Brazil. *Waste Management, 33,* 420–430.

Song, Q., & Li, J. (2015). A review on human health consequences of metals exposure to e-waste in china. *Environmental Pollution, 196,* 450–461.

Tanskanen, P. (2013). Management and recycling of electronic waste. *Acta Materialia*, *61,* 1001–1011. The Diamond Jubilee Issue Materials Challenges in Tomorrowas World Selected Topics in Materials Science and Engineering.

Zhang, K., Schnoor, J. L., & Zeng, E. Y. (2012). E-waste recycling: Where does it go from here? *Environmental Science and Technology*, *46*, 10861–10867.

Solving the Linear Ordering Problem Using a Genetic Algorithm with Local Search

C. Cergibozan and A. S. Tasan

Abstract The linear ordering problem (LOP) is an NP-hard problem in combinatorial optimization. The problem has been investigated in many research areas such as mathematics, logistics, economics, computer science, etc. The complexity motivates researchers to find effective solution methods to the problem. The aim of this study is to develop an efficient algorithm to solve LOP. In this study, a genetic algorithm based approach is proposed for LOP. An additional local search component is embedded in the algorithm to intensify the search. Proposed algorithm is applied to a number of LOP instances taken from the LOLIB. At the end of the computational study, competitive and effective results are found.

Keywords Linear ordering problem · Genetic algorithm · Local search

1 Introduction

Routing problems has been widely studied in the area of combinatorial optimization. Serving to demand points as quickly as possible is one of the aims in the routing problems; however minimizing waiting time of the customer has become a necessity in today's global markets. As a result, routing problems may have different objectives related with the considered problem.

When the priority of importance is given to customers, objective function of the problem is structured according to the situation being talked. In this study, a well-known problem from this class of problems is examined. Linear ordering problem (LOP) which is also known as the triangulation problem mainly focuses on the maximization of the total weights related with the arcs between customer points. The main objective in such a situation is to ensure customer satisfaction in a wide

C. Cergibozan · A. S. Tasan (✉)
Department of Industrial Engineering, Dokuz Eylul University, Izmir, Turkey
e-mail: serdar.tasan@deu.edu.tr

C. Cergibozan
e-mail: cagla.cergibozan@deu.edu.tr

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manner. The problem has been studied with some exact and heuristic/metaheuristic approaches. Therefore in this study, a genetic algorithm for the LOP is developed. The algorithm also includes a local search component which enables an intensive search around good solutions obtained so far.

The paper is organized as follows. In Sect. 2, the LOP is defined, and the literature on solution methods is investigated. In Sect. 3, proposed algorithm is described. In Sect. 4, a computational study is implemented with a number of instances, and finally in Sect. 5, the study is concluded with the results and discussion on future research directions.

2 Linear Ordering Problem

Suppose that $V = \{1, \ldots, n\}$ is the vertex set where n is a positive integer, and A is the arc set where $A = \{(i,j)|i,j \in V, i \neq j\}$ in a complete directed graph D. w_{ij} is defined as the weight of the arc (i, j). Binary decision variable x_{ij} equal to 1 if vertex i precedes vertex j in the acyclic tournament, 0 otherwise. The objective of the problem is to find a linear ordering (or permutation) of the vertices to maximize the total weight $\sum_{i,j} w_{ij}x_{ij}$. Mathematical formulation of the problem can be found in Martí et al. (2012).

The LOP can also be formulated as the *triangulation problem* in the matrix form Martí and Reinelt (2011). Figure 1 displays a descriptive example of LOP. Based on the weights in the matrix M, and the permutation given, the objective function value is found as the sum of the weights of the superdiagonal elements of the matrix M.

$$M_{P_1} = \begin{bmatrix} 0 & 4 & 7 & 4 \\ 4 & 0 & 1 & 10 \\ 5 & 10 & 0 & 1 \\ 8 & 9 & 3 & 0 \end{bmatrix} \qquad P_1 = Permutation\ (1\,2\,3\,4)\ results\ with\ 27.$$

$$M_{P_2} = \begin{bmatrix} 0 & 3 & 9 & 8 \\ 1 & 0 & 10 & 5 \\ 10 & 1 & 0 & 4 \\ 4 & 7 & 4 & 0 \end{bmatrix} \qquad P_2 = Permutation\ (4\,3\,2\,1)\ results\ with\ 39.$$

Fig. 1 Illustrative example of the LOP with the matrix form (triangulation problem)

Table 1 A list of some studies on the LOP literature

Authors	Solution method
Laguna et al. (1999)	Elite tabu search
Campos et al. (2001)	Scatter search
Schiavinotto and Stützle (2004)	Search space analysis, iterated local search and memetic algorithms
Garcia et al. (2006)	Variable neighborhood search
Duarte et al. (2011)	Tabu search
Martí et al. (2012)	A survey on heuristics and metaheuristics
Sakuraba et al. (2015)	Iterated local search, great deluge trajectory

Since the problem is NP-hard, an effective solution approach which yields good results within a reasonable time is important. Some studies from the related literature are listed in Table 1.

It seems there is still a potential research area for developing effective solution techniques for the problem. Therefore in this study, a metaheuristic approach is considered to solve the LOP. Genetic algorithm with a local search heuristic is developed, and the algorithm is described in the following section.

3 Proposed Hybrid Genetic Algorithm

For many years, nature based solution approaches have been applied to the optimization problems. Some of these approaches can be stated as swarm based approaches, and some of them are evolutionary approaches. Genetic algorithms which belong to class of evolutionary algorithms are metaheuristic solution methods for optimization problems (Gen and Cheng 1997). In a genetic algorithm (GA), a population of individuals is artificially evolved along iterations, and the algorithm tries to find the optimal solution to the considered problem in the extensive search space.

In this study, a hybrid genetic algorithm approach is proposed for the LOP. In Fig. 2, flowchart of the proposed GA is given. In the algorithm, a permutation representation is used as the individual. After generation of a random population, fitness values of candidate solutions are structured and calculated according to a maximization problem. Roulette wheel selection and order crossover are used as selection and crossover operators, respectively. Two exchange (swap) operation is used as the mutation operator. After mutation, 2-opt local search heuristic is utilized to improve the solution, in case of survival of the child. Finally, the algorithm is terminated after reaching predetermined number of GA iterations, and the best solution in the population is obtained.

2-opt heuristic is a local search heuristic similar to two-exchange move. Difference between these heuristics is that in 2-opt move, the elements between two

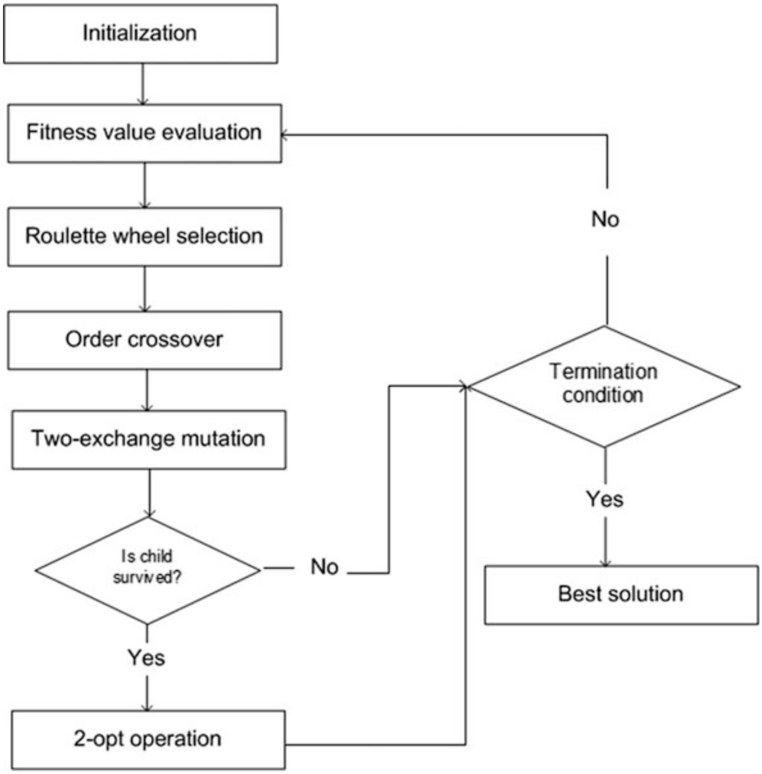

Fig. 2 Flowchart of the proposed genetic algorithm

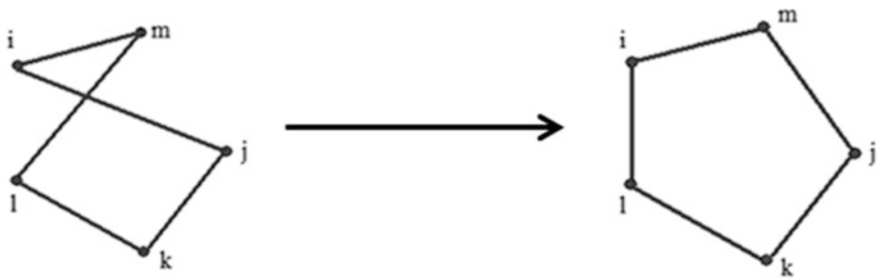

Fig. 3 2-opt move

selected points are sequenced in a reverse way. A simple illustration of the 2-opt move is given in Fig. 3. After removal of arc (*i, j*) and arc (*l, m*), the route (*i, j, k, l, m*) becomes (*i, l, k, j, m*).

According to studies in the related literature, performance of the 2-opt heuristic is found to be effective in graph related problems, therefore in this study, it is chosen as the local search procedure for the problem.

4 Computational Study

Performance of the proposed algorithm is evaluated with a computational study. Best parameter combination is determined by a number of computational experiments. The algorithm is coded in MATLAB software, and performed on a computer with an Intel Core i7-4770 processor with 3.40 GHz and 8 GB Ram.

Parameter values used in the experiments are given in Table 2. These values are important to diversify and also intensify the search within the solution space. Population size (n) is kept as wide and also crossover rate is fixed at a high level for diversification. Other values provide a deeper search in the region of the found solution.

Since the convergence is occurred at the 300 GA iterations in the experimental study, the number of GA iterations is fixed at the level of 300. The crossover and mutation rates are the prevalent values, and number of two exchange and 2-opt iterations are fixed at the trade-off points that provide a fast and effective algorithm while size of the data set is increasing.

The algorithm is tested with the data sets which have been studied in the LOP literature. 14 instances which are based on input-output tables from different economies are selected from the well-known IO instances, and proposed algorithm is implemented. These data sets can be found in Optsicom Project (http://www.optsicom.es/lolib/), and LOLIB (https://www.iwr.uni-heidelberg.de/groups/comopt/software/LOLIB/iomat/).

Table 3 shows the results of the computational study. The algorithm is run for 5 times for each of the instances, and the best and average solutions found via the proposed algorithm are stated in Table 3. Best solutions with refer to Optsicom Project (http://www.optsicom.es/lolib/) for the related instance is displayed in the bounds column, and deviations from the bounds are also computed.

Table 2 Genetic algorithm parameters

Parameter	Value
Population size (n)	300
Crossover rate	0.8
Number of GA iterations	300
Mutation rate	0.2
Number of two exchange iterations	10
2-opt rate	0.5
Number of 2-opt iterations	2000

Table 3 Results of the computational study

Instance	Best result	Bound	Avg.	Deviation % from bound
be75eec	**236,464**	236,464	236239.4	0.000
be75np	716,934	716,994	716883.6	0.008
be75oi	111,165	111,171	111123.4	0.005
be75tot	980,276	980,516	980010.2	0.024
stabu70	361,945	362,512	361585	0.156
stabu74	540,837	541,393	540330.6	0.103
stabu75	552,301	553,303	551828.4	0.181
t59b11xx	**209,320**	209,320	209,296	0.000
t59d11xx	**147,354**	147354	147353.4	0.000
t65b11xx	356,547	356,758	356,096	0.059
t65d11xx	**237,739**	237,739	237383.8	0.000
t70b11xx	528,374	528,419	528272.2	0.009
t70d11xx	376,639	376,725	376567.6	0.023
usa79	1,810,098	1,813,986	1805927.4	0.214

Bold values denote that there is no deviation from the bound

Percentage deviations from the bounds are computed as follows:

$$Dev\% = \frac{|Best - Bound|}{Bound} \times 100 \tag{1}$$

After implementation of the algorithm, it is seen that percentage deviation values are between 0 and 0.2. Computational time of the algorithm varies between 1 and 4 min according to data sets used.

5 Results and Conclusion

In this study, a genetic algorithm with a local search is proposed for the linear ordering problem. Performance of the algorithm is found as efficient and promising, as it finds effective solutions to examined data sets within approximately at most 4 min. Proposed algorithm finds good results with the advantage of the embedded local search heuristic (2-opt), and it is thought that characteristic of the problem is suitable for developing several heuristic approaches.

As a future research, some modifications are thought to be made in the structural design of the problem so as to reduce computational time of the algorithm.

References

Campos, V., Glover, F., Laguna, M., & Martí, R. (2001). An experimental evaluation of a scatter search for the linear ordering problem. *Journal of Global Optimization, 21*(4), 397–414.

Duarte, A., Laguna, M., & Martí, R. (2011). Tabu search for the linear ordering problem with cumulative costs. *Computational Optimization and Applications, 48*(3), 697–715.

Garcia, C. G., Pérez-Brito, D., Campos, V., & Martí, R. (2006). Variable neighborhood search for the linear ordering problem. *Computers & Operations Research, 33*(12), 3549–3565.

Gen, M., & Cheng, R. (1997). *Genetic algorithms and engineering design*. New York: Wiley.

Laguna, M., Martí, R., & Campos, V. (1999). Intensification and diversification with elite tabu search solutions for the linear ordering problem. *Computers & Operations Research, 26*(12), 1217–1230.

Martí, R., & Reinelt, G. (2011) *The linear ordering problem: exact and heuristic methods in combinatorial optimization*, (Vol. 175). Springer Science & Business Media.

Martí, R., Reinelt, G., & Duarte, A. (2012). A benchmark library and a comparison of heuristic methods for the linear ordering problem. *Computational Optimization and Applications, 51*(3), 1297–1317.

Sakuraba, C. S., Ronconi, D. P., Birgin, E. G., & Yagiura, M. (2015). Metaheuristics for large-scale instances of the linear ordering problem. *Expert Systems with Applications, 42*(9), 4432–4442.

Schiavinotto, T., & Stützle, T. (2004). The linear ordering problem: Instances, search space analysis and algorithms. *Journal of Mathematical Modelling and Algorithms, 3*(4), 367–402.

Part III
Logistics, Production and Information System

Reverse Logistics for Return Management in Retail: A Systematic Literature Review from 2007 to 2016

K. T. S. Dias, S. S. Braga Jr., D. Silva and E. G. Satolo

Abstract Business logistics, both integrated and reverse, is an important activity in the supply chain, capable of managing raw materials, stocks, transport and information. With regard to reverse logistics, it is developed in the processes of return management, which plays a critical role in the management of organizations. The retail sector, besides being one of the main recipients of returned products and packaging, plays a fundamental role in the supply chain and has a significant participation in issues of dissemination of social and environmental responsibilities. Thus, given the representativeness of retail and the importance of the reverse logistics activity, this study aimed to analyse the publications of articles, between 2007 and 2016, regarding the use of reverse logistics for the management of returns in retail. Through a systematic literature review, the results show that the studied subject is still in development, since, from the 116 references found, only 10 were considered for the final analysis of this present study. Another factor that reaffirms this evidence is the predominant exploratory character of all the available research, and the fact that half of the studies selected for the final analysis were published in the last year (2016). Furthermore, it was possible identify that advantages obtained by reverse logistics management is, principally, related in economic and environmental scope.

Keywords Reverse logistics · Retail · Return management · Systematic literature review

K. T. S. Dias (✉) · S. S. Braga Jr. · D. Silva · E. G. Satolo
Faculty of Science and Engineering, São Paulo State University (UNESP), Avenue Domingo da Costa Lopes, 780, Tupã 17600, Brazil
e-mail: kaasdias@live.com

S. S. Braga Jr.
e-mail: sergio@tupa.unesp.br

D. Silva
e-mail: dirceuds@gmail.com

E. G. Satolo
e-mail: eduardo@tupa.unesp.br

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1 Introduction

Facing an extremely competitive market, organizations seek to establish effective integration relationships to achieve goals that seek corporate profit through a more competitive supply chain. The success of the supply chain is through the sharing of resources, technologies, and information in order to meet the consumers' needs (Zimmermann et al. 2016).

Business logistics activities, both integrated (downstream) and reverse (upstream), are important in the supply chain. The first one is responsible for planning, implementing, and controlling the flow of storage of goods, services and information from the origin spot to the consumption spot (Beh et al. 2016). The second one, in turn, consists of planning the reverse flow of products and packaging, starting from the consumption spot to be put back into the productive chain, as a by-product or as raw material for other productive chains (Dias and Braga Jr. 2016).

According to Marchesini and Alcântara (2016), reverse logistics activities are directly related to return management, which consists of one of the eight key business processes that are part of the supply chain management. These processes, defined by The Global Supply Chain Forum, cover both downstream and upstream flows and include: customer relationship management; customer service management; demand management; order fulfilment; manufacturing flow management; supplier relationship management; product development and marketing; and returns management (Croxton et al. 2002). Therefore, for the present research, it is understood that the reverse logistics is a subprocess of the returns management in a supply chain.

Reverse logistics can crystallize in a series of perceived advantages in the environmental, economic, social scopes (Braga Jr. and Rizzo 2010, Hernández et al. 2012) and competitive (Rogers and Tibben-Lembke 1998). These factors drive the adoption of this activity by the supply chain organizations, especially in the retail sector, as it is a great propagator of principles and values of social (Parente et al. 2009) and environmental (Dias and Braga Jr. 2016) responsibility, which are strongly linked.

This responsibility of the retail sector is given by its representativeness both in the community in which it is inserted and in the supply chain, since the companies in the sector have direct contact with the final consumer and, therefore, have more information about their needs and desires (Parente et al. 2009).

Thus, given the social and environmental representativeness of the retail sector and the importance of reverse logistics activities for the return of goods and packaging to the supply chain, it is necessary to focus a study relating the importance of reverse logistics in the retail sector. As Bernon et al. (2011) point out, although many authors have contributed to the theoretical development on the application of reverse logistics in retail, this issue can be considered as immature and developing. It should also be noted that no previous studies were found that addressed the state-of-the-art of reverse logistics applications for the management of returns in the industry.

Therefore, the present study seeks to analyze the articles published, over a period of ten years, regarding the use of reverse logistics for the management of returns in retail. Specifically, articles related to the scope of the research were identified through a systematic literature review. The references were analyzed according to the following specific objectives: (i) to identify the evolution of the publications; and (ii) to identify the perceived advantages of reverse logistics.

2 Methods

For the construction of this study, a Systematic Bibliographic Review (SBR) was carried out following the steps proposed by Kubota et al. (2013) to seek the "state of the art" in a methodical, transparent and replicable way to the scientific discussions about the application of reverse logistics in retail (Conforto et al. 2011). Based on the objective of the present research, a search on the publications related to reverse logistics was carried out as a tool for the management of retail returns, in a methodical and replicable way, carried out on August 16th and October 16th, covering the last ten years of publications (2007–2016).

2.1 Selecting and Collecting Data

The basis was ISI Web of Science, in which the main collection was selected. After defining the database, we chose the terms that guided the search for the articles. The definition of the search strings, or search terms, can be given through preliminary searches in related journals or through consultation with experts and researchers (Conforto et al. 2011).

Initially, a preliminary research was carried out with the strings: "reverse logistics"; "retail*". Considering the last 10 years of publication; 1609 results were found for the word "reverse logistics" and 22,972 results for the word "retail*". Through these preliminary tests, the final strings that suit the search were "reverse logistics" AND "retail*".

The results obtained were summarized in 116 files published in the last ten years. With the data library resulting from the preliminary research, we started the filtering processes of the articles to be considered for the final analysis. This process was performed according to the steps proposed by Kubota et al. (2013).

The first step of the selection was by reading the articles in the following sequence: title, abstract and keywords. After this reading, the articles that were not related to what was proposed in the present study were excluded. This first selection step resulted in 19 references to be excluded. The criteria adopted indicate that at least one of the keywords, given by the search terms used, should appear in at least one place, whether in title, abstract or keywords. For this reason, articles that did not present keywords were also disregarded.

After this first exclusion, the second selection step consisted of finding the complete article available for download, in which it was identified that 22 references did not have free access. So, we moved on to the third step.

Another criterion adopted was the publication of articles in periodicals, published in journals of a scientific nature. In this step, we identified 24 articles to be excluded. All references to this criterion were publications of scientific events, including international conferences.

Starting from the possession of these 51 remaining articles, the reading process was started in order: introduction, conclusion, methodology and results. Therefore, the articles should obligatorily present all these topics. Thus, because no methodology had been presented, 3 articles were excluded.

Still in this step, which consisted of the fourth and final stage of selection, 38 articles were identified that had no relation to the scope of the research, not presenting direct relation to retail company or to management of returns in the sector. Thus, the selection process ended, and from the 116 references identified at the beginning of the research, 106 were discarded and 10 articles were considered for the preparation of the research reports, as presented in the following section.

3 Results and Discussions

The 10 article selected were related to the scope of this study. For an initial presentation, Table 1 sets out the authors, year of publication and title of the articles that were analyzed.

Through the systematic literature review, it was possible to identify the evolution of the publications about the theme of reverse logistics for the management of returns applied to retail, including the identification of the number of publications per year, as well in which journals they were published and the methods covered. Finally, some identification is held regarding the perceived advantages regarding reverse logistics in the retail sector.

3.1 Publication Development

It was possible to verify the progress of the publications per year, given the period of ten years (2007–2016), considering the 10 selected articles for the analysis. It is observed that the interest for the subject of reverse logistics for the management of returns in retail is recent and started to gain effective prominence only in 2016. In this year, 05 articles were published, while for the previous years, only 2009, 2010, 2011, 2013 and 2015 presented 01 publication. Thus, 50% of the references that were selected for analysis were published in 2016.

It is important highlight that both of articles was published in scientific journals, and that most publications on the subject of this research are found in the

Table 1 Selected articles for the construction of the analyzes

Author (s)	Year	Title of the article
Hsu, Alexander, and Zhu	2009	Understanding the reverse logistics operations of a retailer: a pilot study
Jack, Powers, and Skinner	2010	Reverse logistics capabilities: antecedents and cost savings
Bernon, Rossi, and Cullen	2011	Retail reverse logistics: a call and grounding framework for research
Mafakheri and Nasiri	2013	Revenue sharing coordination in reverse logistics
Huang et al.	2015	Salient task environment, reverse logistics and performance
Beh et al.	2016	Second-life retailing: a reverse supply chain perspective
Bernon, Cullen, and Gorst	2016	Online retail returns management Integration within an Omni-channel distribution context
Dias & Braga Jr.	2016	The use of reverse logistics for waste management in a Brazilian grocery retailer
Guarnieri, Silva, and Levino	2016	Analysis of electronic waste reverse logistics decisions using Strategic Options Development Analysis methodology: A Brazilian case
Hjort and Lantz	2016	The impact of returns policies on profitability: A fashion e-commerce case

Source Prepared by the author based on the research data

International Journal of Physical Distribution & Logistics Management, which represented a total of 40%, or 04 articles, published in this journal.

Regarding the methods used by the authors, the classification of the research objectives was first identified. In this sense, it was identified that the 10 studies analyzed characterized the objectives as exploratory. This characterization is in line with what Bernon et al. (2011) discuss; stating that research covering this topic is still under development.

In a second moment, the research approaches used in the studies were identified. It was evidenced that there were qualitative approaches, quantitative and mixed approaches, as shown in Table 2, which also shows the data collection instruments that were applied in each approach.

In general, the type of research that stood out the most was the case study, since it was present in 50% of the articles analyzed. This representation included 03 qualitative research studies (Hsu et al. 2009; Beh et al. 2016; Guarnieri et al. 2016) and two mixed-approach studies (Bernon et al. 2016; Dias and Braga Jr. 2016).

3.2 Advantages Perceived of Reverse Logistics in Retail

Throughout the readings of the articles that compose the sampling for the analysis, it was possible to identify that the application of reverse logistics resulted in some

Table 2 Methods and data collection instruments used by authors

Approach	Author(s)	Year	Data collection instruments
Qualitative Research	Hsu, Alexander, and Zhu	2009	Observation and Interview
	Bernon, Rossi, and Cullen	2011	Documentary, Observation and Focus Group
	Beh et al.	2016	Observation and Interview
	Guarnieri, Silva, and Levino	2016	Interview, Brainstorm and Workshop
Quantitative Research	Jack, Powers, and Skinner	2010	Survey
	Mafakheri and Nasiri	2013	Simulation of Scenarios
	Huang et al.	2015	Documentary, Survey and Interview
	Hjort and Lantz	2016	Documentary
Mixed Research	Bernon, Cullen, and Gorst	2016	Documentary, Observation, Interview and Workshop
	Dias and Braga Jr.	2016	Documentary, Observation and Interview

Source Prepared by the author based on the research data

advantages, which were perceived and described by eight papers, crystallize in economic, environmental, social, and competitiveness aspects, which confirms the arguments arouse by Rogers and Tibben-Lembke (1998), Braga Jr. and Rizzo (2010), and Hernández et al. (2012). In this sense, Table 3 shows what aspects were observed as advantages in the analyzed studies per author.

Table 3 Reverse logistics advantages perceived per author

Author (s)	Year	Reverse logistics advantages			
		Economic aspects	Environmental aspects	Social aspects	Competitiveness
Hsu, Alexander, and Zhu	2009	X			X
Jack, Powers, and Skinner	2010	X			X
Bernon, Rossi, and Cullen	2011	X			
Mafakheri and Nasiri	2013		X		
Huang et al.	2015	X	X		X
Beh et al.	2016	X	X	X	
Dias and Braga Jr.	2016	X	X		
Guarnieri, Silva, and Levino	2016	X	X	X	X

Source Prepared by the author based on the research data

It is possible identify, by Table 3, that the economic and environmental aspects receive enhance by the authors. The economic aspect refers about the increased profitability or revenue and cost reduction, given through the management of reverse logistics. About the environmental aspect, this is given by reducing the environmental impact, by means of reducing the amount of waste disposed incorrectly. Another aspect observed is in relation to the social scope, which concerns the generation of employment and income to the population, given from the activities of reverse logistics. Finally, the competitive aspect concerns about the differentiating from competitors, through a well-managed return process and image and reputation improvement.

4 Final Considerations

Bernon, Rossi and Cullen (2011) point out that the theme of reverse logistics applied in retail can be considered as immature and developing. In view of this assertion and the results obtained with the present research, it is evident that, although five years have passed since the publication of the study by the authors mentioned above, the subject studied is still under development, since from 116 references found, only 10 comprised the final analysis of this present study. Another factor that reaffirms this evidence is the predominant exploratory character of the research found.

Although the theme is still in maturity, it has gained relevance, mainly due to the fact that half of the studies selected for the final analysis were published in the last year (2016). Through the research evolution on reverse logistics applied to retail, effective contributions may help in complementing the literature, as well as in the returns management processes that are adopted by organizations and, thus, generate improvements in the management of these activities.

Regarding the advantages perceived through the adoption of reverse logistics activities, the studies pointed out that these can crystallize in economic, environmental, social and competitive aspects. It was evidenced that the perception given in each of these aspects corresponds to what the authors Braga Jr. and Rizzo (2010), Hernández et al. (2012), and Rogers and Tibben-Lembke (1998) address in their studies.

It noted that there is a predominance of approach to the advantages of reverse logistics in the economic and environmental aspects. This emphasis is justified by the constant search for corporate profit, which can give organizations market advantages, as well as indicating good management of administrative processes, meeting consumer needs and legal requirements regarding environmental issues.

The economic aspect is more complex. In order to be favorable, it is necessary to consider the costs incurred on the reverse logistics activity and to compare them with the revenues obtained. Thus, costs such as: labor, storage, machinery and equipment, water, energy, and others must be considered. Therefore, recommended to carry out in-depth studies in the financial scope of reverse logistics to verify if activity can be considered as generating economic advantage. It should be emphasized that none of the articles analyzed addressed this aspect in depth.

However, as a suggestion for future studies and for a more effective and complete mapping, it is necessary to expand the search in a broader temporal period and in more databases of scientific character, such as the bases Scopus and Scielo, for example.

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References

Beh, L. S., Ghobadian, A., He, Q., Gallear, D., & O'Regan, N. (2016). Second-life retailing: A reverse supply chain perspective. *Supply Chain Management: An International Journal, 21*(2), 259–272.

Bernon, M., Cullen, J., & Gorst, J. (2016). Online retail returns management: Integration within an omni-channel distribution context. *International Journal of Physical Distribution & Logistics Management, 46*(6/7), 584–605.

Bernon, M., Rossi, S., & Cullen, J. (2011). Retail reverse logistics: a call and grounding framework for research. *International Journal of Physical Distribution & Logistics Management, 41*(5), 484–510.

Braga, S. S., Jr., & Rizzo, M. R. (2010). Sustentabilidade através do aproveitamento de resíduos: Um estudo dos processos implantados por um supermercado de médio porte. *Revista Brasileira de Engenharia de Biossistemas, 4*(2), 108–125.

Conforto, E. C., Amaral, D. C., & Silva, S. L. (2011, September). Roteiro para revisão bibliográfica sistemática: aplicação no desenvolvimento de produtos e gerenciamento de projetos. In 8º Congresso Brasileiro de Gestão de Desenvolvimento de Produto-CBGDP.

Croxton, K. L., Lambert, D. M., García-Dastugue, S. J., & Rogers, D. S. (2002). The demand management process. *The International Journal of Logistics Management, 13*(2), 51–66.

Dias, K. T. S., & Braga, S. S., Jr. (2016). The use of reverse logistics for waste management in a Brazilian grocery retailer. *Waste Management and Research, 34*(1), 22–29.

Guarnieri, P., e Silva, L. C., & Levino, N. A. (2016). Analysis of electronic waste reverse logistics decisions using Strategic options development analysis methodology: A Brazilian case. *Journal of Cleaner Production, 133,* 1105–1117.

Hernández, C. T., Marins, F. A. S., & Castro, R. C. (2012). Modelo de gerenciamento da logística reversa. *Gestão & Produção, 19*(3), 445–456.

Hjort, K., & Lantz, B. (2016). The impact of returns policies on profitability: A fashion e-commerce case. *Journal of Business Research, 69*(11), 4980–4985.

Hsu, H. S., Alexander, C. A., & Zhu, Z. (2009). Understanding the reverse logistics operations of a retailer: A pilot study. *Industrial Management & Data Systems, 109*(4), 515–531.

Huang, Y. C., Rahman, S., Wu, Y. C. J., & Huang, C. J. (2015). Salient task environment, reverse logistics and performance. *International Journal of Physical Distribution & Logistics Management, 45*(9/10), 979–1006.

Jack, E. P., Powers, T. L., & Skinner, L. (2010). Reverse logistics capabilities: Antecedents and cost savings. *International Journal of Physical Distribution & Logistics Management, 40*(3), 228–246.

Kubota, F. I., Ferenhof, H. A., Ferreira, M. G. G., Forcellini, F. A., & Miguel, P. A. C. (2013). Desenvolvimento de Plataforma de Produto e Modularidade: uma análise bibliométrica. *TPA-Teoria e Prática em Administração, 3*(2), 44–69.

Mafakheri, F., & Nasiri, F. (2013). Revenue sharing coordination in reverse logistics. *Journal of Cleaner Production, 59,* 185–196.

Marchesini, M. M. P., & Alcântara, R. L. C. (2016). Logistics activities in supply chain business process: A conceptual framework to guide their implementation. *The International Journal of Logistics Management, 27*(1), 6–30.

Parente, J., Macedo, L.C., Cardoso, R. C., & Ferreira, V. (2009). Varejo e responsabilidade social. In: Parente, Juracy; Gelman, Jacob J. Varejo e responsabilidade social. Bookman Editora, Cap. 1, 15–30.

Rogers, D. S., & Tibben-Lembke, R. S. (1998). The impact of reverse logistics on the total cost of ownership. *Journal of Marketing Theory and Practice, 6*(4), 51–60.

Zimmermann, R., Ferreira, L. M., & Moreira, A. C. (2016). The influence of supply chain on the innovation process: A systematic literature review. *Supply Chain Management: An International Journal, 21*(3), 289–304.

Risk Identification and Its Generating Factors in a Supply Chain from the Natural Gas Sector

F. S. Tomé, E. R. S. Silva and M. S. A. Leite

Abstract The complexity of chains, their vulnerabilities to internal and external risk factors and their relationships, have caused the managers of organizations to analyze the risk within the supply chain. This insight has led companies to seek ways to establish a relationship between processes and principles that reduce the occurrence of risks and can mitigate them and improve their competitiveness. The identification of the risk does not occur in an isolated way in the chain, and can propagate along its extension. Thus, the purpose of this article is to identify the risks and their generating factors that occur internally at a supply chain link of a natural gas industry. In the Research Methodology, we used the application of semi structured interviews and application of questionnaires and for the validation of risks we used the method of focal group. The results obtained include the identification of internal risks in the studied companies and their risk-generating factors as well as the common risks between companies, highlighting vulnerability points such as: outsourcing, increased dependence on suppliers, economic and political crises, to which the chain is exposed.

Keywords Risk identification · Risk management · Natural gas

F. S. Tomé (✉) · M. S. A. Leite
Production Engineering Department, Federal University of Paraíba, João Pessoa, Brazil
e-mail: felipestome@hotmail.com

M. S. A. Leite
e-mail: mariasileneleite@hotmail.com

E. R. S. Silva
Federal University of Itajubá—Math and Computer Science Institute, Itajubá, Brazil
e-mail: sanches.elizabete@gmail.com

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1 Introduction

In modern business environments, manufacturers are increasingly under pressure to meet their customers' requirements by customizing their products, improving quality, and responding quickly (Chan et al. 2012). As a consequence of the high dynamicity of the market, customers require shorter lead times, low cost, high quality and diversified products (Ip et al. 2011).

For organizations to sustain the business under these pressures, more and more companies are striving to develop long-term strategic partnerships with their suppliers and collaborate on product development, inventory control, and outsourcing processes (Chan et al. 2012).

In this regard, the number of companies seeking a stable relationship with their partners is increasing, with the intention of reducing costs, sharing risks and improving competitive advantage. The logic of the supply chain seeks collaboration among members, with the intention of making partners stronger in the market and strengthen relations (Xiao et al. 2010; Papakiriakopoulos and Pramatari 2010; Cook et al. 2011). This chain is conceived as a set of activities that encompass business functions of coordination and receipt of raw materials, product manufacturing through distribution and delivery to the customer (Xu 2011).

The supply chain becomes more complex and vulnerable in the global scenario, the greater the existence of heterogeneous environments in different regions (Shing et al. 2012). In these environments risk management is evidenced, based on the efforts made to reduce this vulnerability, implying the eminent need of organizations to develop necessary risk management strategies and their interruptions (Giannakis and Louis 2011). According to Monroe et al. (2014), the risks present in the supply chain occur due to characteristics of the chain itself, which create vulnerabilities and possible interruptions, resulting in negative damages to organizations.

Supply Chain Risk Management (SCRM) involves identifying sources of risk and seeking ways to prevent or reduce the negative impact of a given event. It is observed that SCRM is an important part of the supply chain management, because the risks can cause unexpected changes in the flow of materials along the chain (Aqlan and e Lam 2015). In this respect, Ritchie and Brindley (2007) point out that risk management is making a significant contribution in the fields of decision making, management and control. The nature and evolution of risk management in the supply chain suggests that global competition, technological change and the pursuit of competitive advantage are the main reasons why organizations pay special attention to risk management approaches.

In this context, the objective of this work is to identify the types of risks and their generating factors, which occur at the internal level of a supply chain link of a natural gas industry.

2 Methodology

This article was elaborated through a systematic review of the literature and a case study, which according to Cauchick Miguel (2010) is an empirical work that investigates a given phenomenon within a real contemporary context, deepening one or more objects of analysis (cases). It allows in-depth analysis on a given topic, although it does not allow generalization. The case study was carried out in the service sector considering the supplier-focal link. To define the supplier-focal link and the key business process, an immediate supply chain mapping was performed. The types of risks that helped to identify them and their generating factors, as well as ways to evaluate them, were raised in the literature. The steps in the preparation of this study are described in Fig. 1.

Selection of companies: In the first stage, a meeting was held with the managers of the focal company, named in this research as Company A, to define the client company as the object of this study. Two of its suppliers were chosen in the process of converting LPG into Natural Gas, denominated in this article as Supplier 1 and Supplier 2. The first supplier acts in the natural gas conversion process in the city of João Pessoa (Paraíba) and the second one operates in the same process in the city of Campina Grande (Paraíba).

Preparation of a questionnaire: A questionnaire was drawn up, based on the systematic review, to collect information on the sources of risk in the selected companies. Selection of companies: In the first stage a meeting was held with the managers of the focal company, named in this research as Company A, to define the client company as the object of this study. Two of its suppliers were chosen in the process of converting LPG into Natural Gas, denominated in this article as Supplier 1 and Supplier 2. The first supplier acts in the natural gas conversion process in the city of João Pessoa and the second one operates in the same process in the city of Campina Grande.

Data survey: Survey of information from the application of questionnaire and interviews, through visits to the focal company and supplier companies (Supplier 1 and 2). The interview involved collaborators related to natural gas production and conversion activities (managers, analysts and operational technicians), also performing an on-site monitoring of this process.

Data processing: The focal group was used to validate the identification of risks that were multiple in the responding companies. For the execution of the technique, there were four representatives of the focal company, two representatives of Supplier 1 and one representative of Supplier 2. The procedures used in this stage

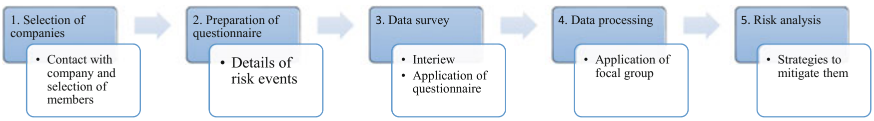

Fig. 1 Research methodology

were: 1. Presentation of the risk factors and their identification; 2. Reallocation of factors to the types of risks; 3. Validation of reallocation between companies and; 4. Identification of the origin of the risk factor among the companies studied (focal and suppliers).

Risk analysis: the relevant risks and their sources were listed.

3 Risk Identification in a Natural Gas Chain

The service sector in Brazil is the one with the greatest participation in product and employment in the country. This sector involves different branches in the national accounting: transportation, communications; trade; financial institutions, public administrations, etc. The services sector, from 2003 to 2013, went from 64.7 to 69.4% of the value added of GDP. The services have gained space in the GDP, according to the Quarterly National Accounts of IBGE.

Figure 2 highlights the link studied in this research with service providers of the gas conversion process: Supplier 1 (ENGEAR Company) covering the residential segment and Supplier 2 (Dr. Fogão) in the commercial segment. PBGÁS, company focus of the study, is responsible for the entire gas distribution process in the state of Paraíba. The selected supplier companies have a contract for the conversion service.

From the understanding of the chain studied, it was possible to identify the present risks. Table 1 presents ten internal risks and the generating factors established in the Focal Company and validated by the focal group. These risks presented common risk-generating factors, such as, "delay in building networks and branches", being a generator factor for the types Logistical Risk and Operational

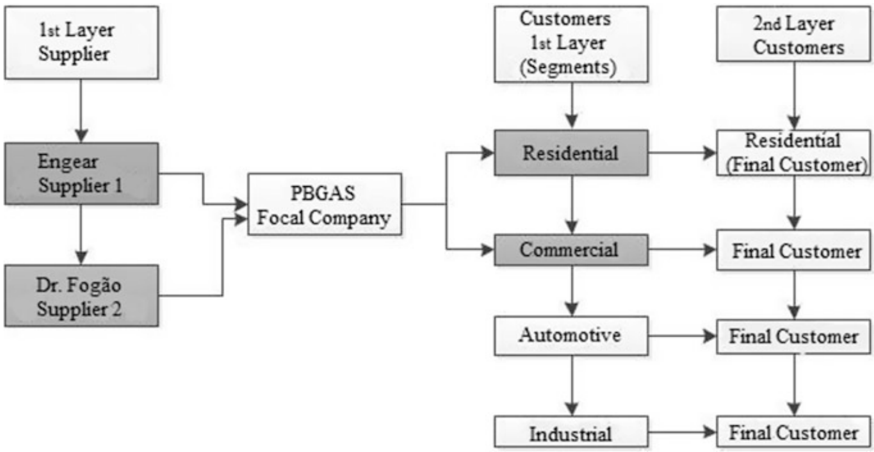

Fig. 2 Supply chain mapping

Table 1 Risk identification in PBGAS (focal company)

Types of risk	Risk-generating factors
Logistical	1. Delay in supply of parts 2. Other distribution companies affect the natural gas piping 3. Difficulty accessing the warehouse 4. Delay in building networks or branches
Operational	1. Delay in building networks or branches 2. Lack of skilled labor 3. Problems that occur in the assembly of networks or extensions 4. Difficulty in relationships between employees 5. Lack of interactivity between the areas in the own company 6. Other distribution companies affect the natural gas piping
Process/control	1. Absence of supervision 2. Trade policies 3. Wage discrepancy
Capacity/resource	1. Lack of skilled labor 2. Performance reduction of hired companies 3. Lower acquisition of equipment
Reputation	1. Meet deadlines related to customers 2. Delay in customer service 3. Poor execution of customer service
Information	1. Customer data management 2. Disturbances in electronic systems 3. Mismatched information from the focal company 4. Lack of tools and difficult access 5. Information reliability
Legal	1. Government policies and norms 2. Difficulty of environmental licenses 3. Attention to contracts 4. Delay in bidding processes
Inventory	1. Lack of supplies for contracts 2. Delay in bidding processes
Fiscal	1. Municipal, state and federal taxes 2. Government policies and norms
Strategic	1. Lack of Marketing 2. Failure in quantitative customer planning 3. Changes in the company's commercial policy 4. Lack of knowledge of the competitor

Source Self elaboration

Risk. Another generating factor that can be highlighted is "other distribution companies affect the natural gas pipeline" that originates the types Logistical Risk and Operational Risk. Also the generator factor "delay in the bidding processes" originate the type Stock Risk and Legal Risk.

In the company Engear, Internal Risk, for example presented the generating factor "lack of information on CRM calling scheduling and interconnect", this one was reallocated to Information Risk. The generating factor of Rupture Risk was reallocated to Supplier Risk, these factors were reallocated due to the better understanding of the respondents about the characteristics of the risks. Thus, Table 2 presents the internal risks and their generating factors.

Table 2 shows that there is a common generating factor due to their similarity to different types of risks, so their identification is extremely effective because a risk factor can be found at more than one risk. To illustrate, the generator factor "lack of skilled labor" is used, which raises the Capacity/Resource risk, as well as Operational Risk. The next table presents the risks found in the company Dr. Fogão.

Although the conversion process is the same, the perception of the suppliers is different regarding the risks and the generating factors. For example, Information Risk appears on Supplier 1, but it does not occur on Supplier 2. Another point to highlight is the different perceptions of the same risks, but with different risk-generating factors among the suppliers, as shown in Table 3.

4 Analysis of Results

In the identification phase it was verified that the risk-generating factors can cause more than one risk. This information is important so that, in the mitigation process, it is possible to combat more than one risk type, as its generating factor is reached. Mitigation occurs when the company begins to take steps in its operations to lessen

Table 2 Risk identification Engear (Supplier 1)

Types of risk	Risk-generating factors
Capacity/resource	1. Conversion in buildings that have heater and no conversion kits available 2. Lack of skilled labor
Operational	1. Problems that occur in assemblies of primary and secondary network 2. Lack of qualified labor, because of the lack of courses focused on the area of natural gas 3. Change of outsourced companies. e.g.: Branches company affects conversions
Reputation	1. Services that are poorly done, pending on services performed, time etc. 2. Poor quality of services performed, customer complains of the delay in the execution of service
Assets depreciation	1. Lack of services responsible for the Focal Company, thus taking time to pass on other services
Fiscal	1. Lack of monthly documentation and the focal company does not pass the appeal
Legal	1. Lack of safety and norms 2. Restrictions exist in the census of the building preventing conversion
Information	1. Transfer of erroneous information from the customer to the focal company and from this to the supplier 2. Lack of information on CRM calling scheduling (Register Box of measurement of gas volume and pressure) and interconnects

Source Self elaboration

Table 3 Risk identification Dr. Fogão (Supplier 2)

Types of risk	Risk-generating factors
Capacity/ resource	1. Processes depend on the skill of technicians 2. Need to always hire more people because services vary greatly 3. Work in the measurement system which entails the purchase of material and salary in advance
Operational	1. Lack of skilled and committed labor
Reputation	1. Existence of equipment of indispensable use by the quality, being able to cause problems in the installation. e.g.: gas meter
Assets depreciation	1. Underutilization of the team, due to lack of programming from the focal company
Organizational/ network	1. Lack of communication due to the process

Source Self elaboration

the impact that the risk can cause and also its existence, with strategy developed with its suppliers and customers.

Another advantage of the study was to analyze the different perceptions of respondents regarding the identification of risk among suppliers. Supplier 1 (ENGEAR), for example, identified 7 types of internal risks (Capacity/Resource, Operational, Reputation, Assets Depreciation, Fiscal, Legal, Information), described as directly present in the conversion process. Supplier 2 (Dr. Fogão) identified 5 types of internal risks (Capacity/Resource, Operational, Reputation, Assets Depreciation and Organizational/Network).

It is noted that there was a divergence in two types of risks between suppliers 1 and 2 (Information and Fiscal Risk). The main reason was that Supplier 1 has more monthly services in the city of João Pessoa than Supplier 2, which has the gas conversion service in the city of Campina Grande. Regarding the focal company, it is observed that two risks that were not identified in the suppliers' responses appear in the responses of the focal company: Strategic and Inventory Risk. Table 4 presents the risks identified in both members.

Table 4 Similarity between risks in the conversion of LPG to natural gas

Type of risk	Risk-generating factor
Logistic	1. Other distribution companies affected piping 2. Delay in building networks or branches
Operational	1. Delay in building networks or branches 2. Lack of specialized labor 3. Excavation from another company having rupture of the pipe
Capacity/resource	1. Lack of skilled labor 2. Poor performance of hired companies
Reputation	1. Failure to comply with deadlines related to the client. 2. Poor execution of services
Information	1. Mismatched information to the focal company

Source Self elaboration

5 Final Considerations

As discussed, risk identification and assessment are two important steps that help to analyze the vulnerabilities to which the chain studied is exposed. At the first moment it was possible to identify the existing risks and their generating factors and at the second moment to analyze these factors. The importance of risks and factors described as similar are highlighted in Table 4, since they were identified in both members. However, there are also other risks that are relevant to the specifics of each member, such as Assets Depreciation, Strategic Risk and Inventory Risk, which must be analyzed by each member at the time they deem most appropriate and necessary.

It should be noted that the risk does not occur in isolation, mainly in the process studied where the gas conversion service is done through a bidding process. It is up to the companies in the immediate supply chain to analyze how these risks and their generating factors behave so they can make more effective risk control decisions in their supply chain.

As future work, one can analyze the dependence between risks by verifying that one company can originate the risk to another and also do a risk assessment through prioritization, so it can list the risks they need as more urgent for control and possible treatment.

References

Aqlan, F., & e LAM, S. (2015). A fuzzy based integrated framework for supply chain risk assessment. *International Journal Production Economics, 16,* 54–63.

Chan, R. Y. K., et al. (2012). Environmental orientation and corporate performance: The mediation mechanism of green supply chain management and moderating effect of competitive intensity. *Industrial Marketing Management, 41*(4), 621–630.

Cook, L. S., Heiser, D. R., & Sengupta, K. (2011). The moderating effect of supply chain role on the relationship between supply chain practices and performance: An empirical analysis. *International Journal of Physical Distribution & Logistics Management, 41*(2), 104–134.

Giannakis, M., & Louis, M. (2011). A multi-agent based framework for supply chain risk management. *Journal of Purchasing and Supply Management, 17*(1), 23–31.

Ip, W. H., Chan, S. L., & Lam, C. Y. (2011). Modeling supply chain performance and stability. *Industrial Management & Data Systems, 111*(8), 1332–1354.

Monroe, R. W., Teets, J. M., & Martin, P. R. (2014). Supply chain risk management: An analysis of sources of risk and mitigation strategies. *International Journal of Applied Management Science, 6*(1), 4–21.

Papakiriakopoulos, D., & Pramatari, K. (2010). Collaborative performance measurement in supply chain. *Industrial Management & Data Systems, 110*(9), 1297–1318.

Ritchie, B., & Brindley, C. (2007). Supply chain risk management and performance: A guiding framework for future development. *International Journal of Operations & Production Management, 27*(3), 303–322.

Singh, A. R., et al. (2012). Design of global supply chain network with operational risks. *The International Journal of Advanced Manufacturing Technology, 60*(1–4), 273–290.

Xiao, Y., et al. (2010). Trust, relationship commitment and cooperative performance: supply chain management. *Chinese Management Studies, 4*(3), 231–243.

Xu, L. D. (2011). Information architecture for supply chain quality management. *International Journal of Production Research, 49*(1), 183–198.

Environmental Aspects in Value Stream Mapping: A Literature Review and Future Directions

Daniel Lorenzon dos Santos and Lucila Maria de Souza Campos

Abstract Although Lean Manufacturing has becoming an important theme of research, the connection between Lean and Green on the supply chain is still a topic recently studied. The main objective of this research is to identify methods used in order to identify wastes in Lean and Green areas and also discuss the synergies and differences between all methodologies available in current literature. This chapter is constructed to address four primary issues: (i) Collect research on databases and categorize the main articles already published; (ii) Understand the most significant journals, contributing authors, and relevant articles commonly cited; (iii) Analyse results and contributions from each article and comment on a relationship between the articles; and (iv) Reach conclusions that direct the focus to future research. Studies were elicited from significant research databases. 19 articles were chosen as most relevant, and we observed that almost 50% of the articles were published within the last three years (2014–2016). As main results we can highlight that the methods for deployment of Lean and Green philosophies need to be spread across the industries. The US Toolkit is the most used methodology, and Sus-VSM methodology appears to be the latest, trendiest topic. The majority of Lean and Green researchers on the supply chain do not use VSM techniques for systematic waste elimination; instead, waste searching and elimination is done without a specific methodology. During this research, we identified some essential points for Environmental VSM techniques, including the importance of connection with other methodologies/policies and the importance of establishing correct indicators. The main indicators found were: Energy consumption (kwh), Water Consumption (kg or litters), Raw material consumption (kg), emissions (kg or kg CO^2) and garbage (kg). Beyond that, case studies need to pursue wider and deeper applications that technically show the improvements and benefits of using sustainable VSM.

D. L. dos Santos (✉) · L. M. de Souza Campos
Programa de Pós-graduação em Engenharia de Produção,
Universidade Federal de Santa Catarina, Caixa Postal 476,
Campus Universitário, Trindade, Florianópolis, Brazil
e-mail: Daniel_lorenzon@yahoo.com.br

L. M. de Souza Campos
e-mail: lucila.campos@ufsc.br

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Practitioners of Lean Manufacturing need to add environmental tools into their research on supply chains, because utilizing such tools can lead companies to reach their environmental goals and can improve society to more effectively use resources.

Keywords Value stream mapping · Environmental · Sustainable
Waste elimination

1 Introduction

The efforts of companies to improve manufacturing processes have created substantial opportunities for environmental improvement. Innovation in the manufacturing process is an incentive for the adoption of environmentally conscious manufacturing (Florida 1996). Lean manufacturing and environmentally sensitive management practices are synergistic in terms of their focus on reducing wastes and inefficiency. However, lean manufacturing by itself will not improve environmental performance, so the emphasis of lean manufacturing should be extended to a focus on environmental waste reduction (Yang et al. 2011).

Different studies have tried to combine Lean and Green initiatives, such as the study by Vinodh et al. (2016) that researched practices in place for many companies in India. This study concluded that bringing lean and sustainable systems together can benefit not only the manufacturers and customers, but also for the environment.

Lean manufacturing measurements need to be more robust and a wider range of environmental performance indicators must be used (Martínez-Jurado and Moyano-Fuentes 2014). Lean manufacturing's main tool is the Lean Value Stream Mapping (VSM), and Green Manufacturing primarily uses the Life Cycle Assessment (LCA) tool. Between the two paradigms, there are some shared tools (Dües et al. 2013).

Edtmayr et al. (2016) developed environmental indicators to evaluate each process on VSM: the scrap accumulation rate and the waste created in a single process are the two most essential indicators used. Garza-Reyes et al. (2016) extended the methodology of Transportation Value Stream Mapping (TVSM) from Villarreal (2012). The concept of sustainability was incorporated with Norton (2007), and that transformed the methodology into Sustainable Value Stream Mapping (STVSM).

A study on lean and green principles launched by Garza-Reyes (2015) covered several aspects, including proposals of assessments/methodologies to measure and evaluate the theme, perspectives to understand future research, and the need to increase knowledge about the characteristics of an effective lean-green assessment method/indicator. Current lean and green measurement methods and models already proposed in the academic literature need to be tested or adapted to different processes or industries.

Faulkner and Badurdeen (2014) present a methodology named Sustainable Value Stream Mapping (Sus-VSM), which includes metrics to evaluate the environmental and societal sustainability performance of a manufacturing line. Their intention was to develop a generic methodology that can apply across a broad range of industry sectors. The authors suggest that further studies, involving additional case studies and applications to other industry sectors, could help create a portfolio of sustainability metrics. Verrier et al. (2016) developed a lean and green house-based study on state-of-the-art research. One of the definitions to conduct the action is the Green VSM based on Faulkner and Badurdeen's Sus-VSM (2014).

The objectives of this study are to ensure a review of the literature from Sus-VSM and to understand the synergies and differences between lean and green and the theme. It is vital to understand all available tools and case studies currently available.

2 Method

The method defined for full research should reach the purposed objectives. The present study researched the theme on four databases and included additional results garnered from Google Scholar. After titles, abstracts and full-text alignment filtering steps were completed, 19 articles were studied as the main collection of knowledge.

The keywords used for the research were split into three focus areas: (1) Green ("Green Management," "Green Manufacturing," "Sustainability," "Lean and Green," "Green Practices," and "Sustainable manufacturing"), (2) Lean ("Lean Manufacturing" or "Lean Practices") and (3) Mapping ("Sus-VSM" or "Value Stream mapping"). The research databases included (i) Scopus, (ii) Web of Science, (iii) ScienceDirect, and (iv) Emerald Insight, and this search was completed on July 16, 2016. The first step produced 1535 articles, and after the duplicated titles were excluded, 562 articles remained. An analysis of title alignment narrowed the collection further to 163 articles. Finally, 63 articles moved forward for full reading and 19 articles were selected for the main component of the study.

3 Results and Discussion

A comprehensive analysis of the literature was conducted during this research. Through the method presented earlier, several different approaches may be entertained through the work of these authors and their respective visions.

Journal of Cleaner Production represents more than 40% of the publications as seen in Fig. 1. Garza-Reyes and Faulkner and Badurdeen have two reviews published and are the top publishers. Dües et al., Martínez-Jurado and Moyano-Fuentes, Paju et al., Faulkner and Badurdeen, and Brown et al. are the most frequently cited articles. Almost 50% of the articles were published in the last three years (2014–2016).

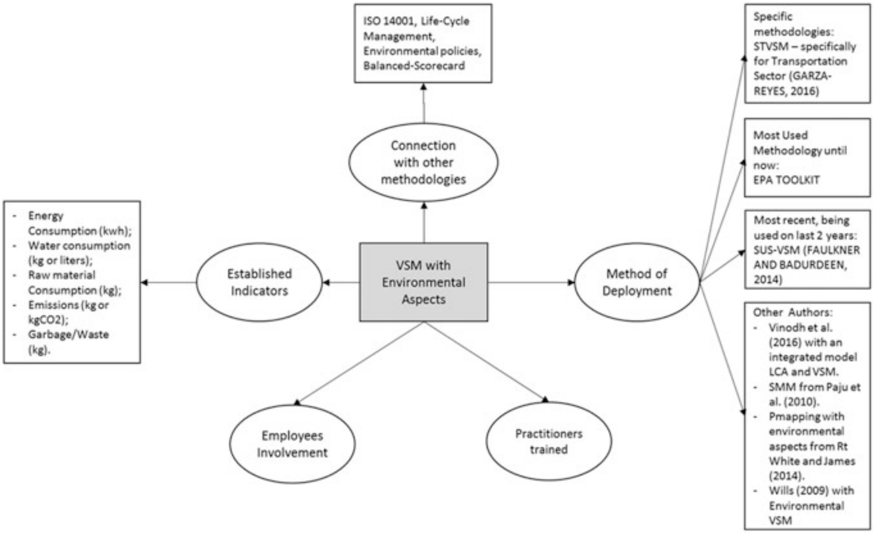

Fig. 1 Framework of relationship from VSM with environmental aspects

Dües et al. (2013) state that no method of green and lean waste's identification has been confirmed as a standard method. Later, Garza-Reyes (2015) confirms that methods and models need to be integrated as future research. The main references from the theme can be seen in the Framework of Fig. 2 and are described in Table 1.

The most used method of VSM with Environmental aspects was the US governmental toolkit (EPA 2007). Other authors have applied this methodology on different sectors including the alcohol and sugar industry, construction sector, automotive industry, and the agrifood supply chain. This method is a suggestion of how to implement lean and green by a mapping process methodology. The essential structure is to select a product family, employ current state mapping, then consider future state mapping, define a working plan, and achieve the working plan. The most commonly cited indicators are water and energy consumption, VA (Value added), NVAA (necessary-non-value-adding time), and NVA (non-value-adding time).

Wills (2009) also developed a method for environmental mapping, Dadashzadeh and Wharton (2012) applied the method to an IT company, and Darmawan et al. (2014) applied it to a natural rubber supply chain.

Ng et al. (2015) used the indicator Carbon-Value Efficiency (CVE) that gives an indication of the proportion of value added activities per environmental impact. Through the use of CVE-VSM, production lead time and value added time for the current state were captured. The results clearly demonstrate that companies can achieve quantitative benefits by integrating and implementing lean and green practices.

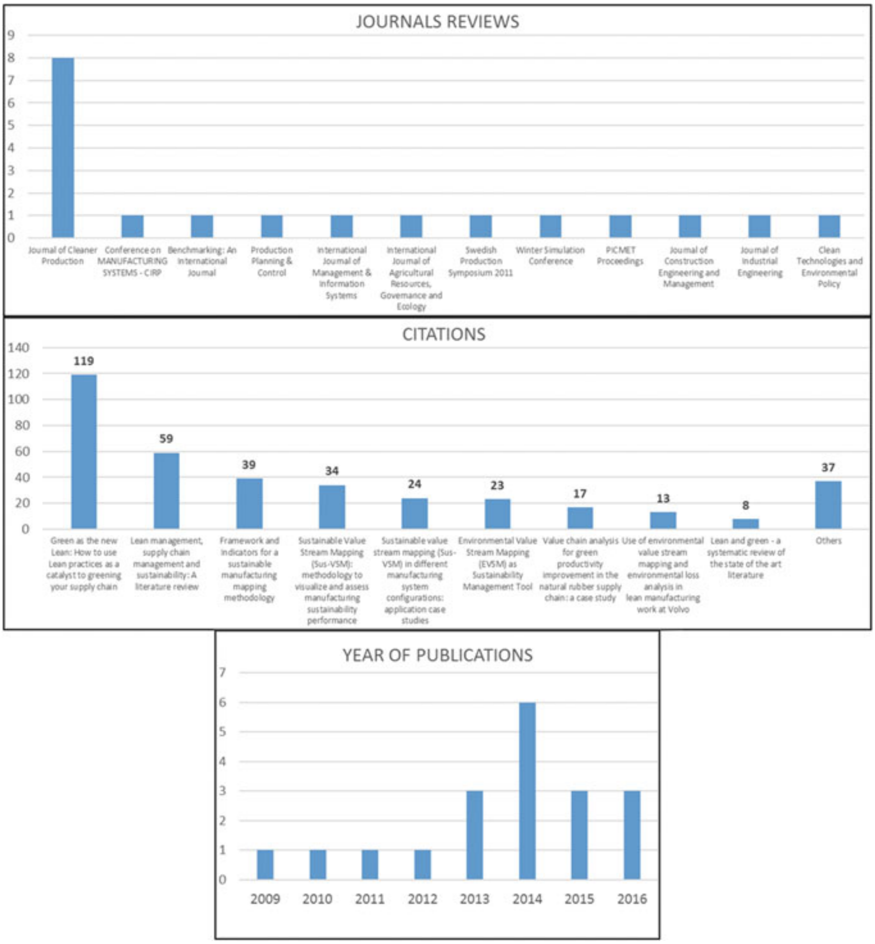

Fig. 2 Data for Number of reviews for each Journal, Reviews citations and year of publication

Recently, other methods have been developed that appear fruitful. Faulkner and Badurdeen (2014) established the S-VSM method; they present a methodology designed to prepare a sustainable VSM (Sus-VSM), which includes metrics to evaluate the environmental, and societal sustainability performance of a manufacturing line. They employ visual symbols for each proposed metric on the Sus-VSM. Further studies, through additional case studies and applications to other industry sectors, could help create a portfolio of sustainability metrics sector-by-sector basis.

Garza-Reyes et al. (2016) established a method for environmental wastes mapping in the transportation sector originally developed from Villarreal (2012). The authors applied the method, an extension of the TVSM methodology, at a company and it has reached good results. The paper combines the lean and green paradigms through a systematic methodology that deploys lean and green

Table 1 List of References relating the Indicators, Methods and Results

#	Author	Title	Environmental Indicators	Methods	Results/ Conclusion
1	Edtmayr et al. (2016)	An Approach to Integrate Parameters and Indicators of Sustainability Management into Value Stream Mapping	- Cumulated scrap rate - Waste at single processes	- VSM drawing - Indicators Calculating	- The use of Sustainable VSM helps to immerse on resource's improving efficiency
2	White and James (2014)	Extension of process mapping to identify "green waste"	-	- Pmapping drawing - Interviews, and process observing	- The technique is useful for an organization to prioritize its efforts to improve its environmental impact - Identifying the technical aspects is often difficult
3	Dües et al. (2013)	Green as the new Lean: How to use Lean practices as a catalyst to greening your supply chain	-	-	Identify Value Stream Mapping as the main tool from Lean Manufacturing, and separately Life-Cycle Assessment Green Manufacturing uses the as the main tool
4	Ng et al. (2015)	Integrating and implementing Lean and Green practices based on proposition of Carbon-Value Efficiency metric	- Carbon-Value Efficiency (CVE) - Carbon Footprint (CFP) based on Energy, Material and Transport (Kg CO2)	- Current state Assessment (VSM) - Future state analysis - Kaizen Events - Action Plans	- Carbon-Value Efficiency improvements by 35%, lead time reduction and carbon footprint reduction - Green and Lean practices can bring benefits for companies
5	Garza-Reyes (2015)	Lean and green—a systematic review of the state of the art literature	-	-	Futures researches need to increase knowledge about the characteristics of an effective lean-green assessment method or indicator

(continued)

Table 1 (continued)

#	Author	Title	Environmental Indicators	Methods	Results/ Conclusion
6	Garza-Reyes et al. (2016)	Lean and green in the transport and logistics sector—a case study of simultaneous deployment	- CO_2 emission per route - NOx emission per route - Equivalent from oil - HC per route - Materials per route	- Mapping Process - Analyze Causes of Wastes and define Strategy for improvements - Pilot Implementation - Full strategy implementation	- STVSM tool is an effective approach to improve road transport operations, the studied organization improved both operational efficiency and environmental performance
7	Verrier et al. (2016)	Lean and Green strategy: the Lean and Green House and maturity deployment model	-	- VSM is part of a Lean and Green Deployment method	- VSM is part of a organizational strategy of enhancing the involvement of employees. The efficiency is based on a strong bond between top-down and bottom-up management
8	Martínez-Jurado and Moyano-Fuentes (2014)	Lean management, supply chain management and sustainability: A literature review	-	-	Robust Lean Manufacturing measurement need to be constructed and a wider range of environmental performance indicators must be used
9	Brown et al. (2014)	Sustainable Value Stream Mapping (Sus-VSM) in different manufacturing system configurations: application case studies	- Raw material usage - Energy Consumption - Water Consumption - Ergonomics	- Map the actual state - Metrics definition	- S-VSM applied on three different manufacturing systems - Suggests further research to extend the Sus-VSM to additional

(continued)

Table 1 (continued)

#	Author	Title	Environmental Indicators	Methods	Results/ Conclusion
					case studies to validate those methods is necessary
10	Faulkner and Badurdeen (2014)	Sustainable Value Stream Mapping (Sus-VSM): methodology to visualize and assess manufacturing sustainability performance	- Raw material usage- Energy Consumption- Water Consumption	- Map the actual state- Metrics definition- Use of different tools - Ergonomic Analyses, for example	- Sus-VSM must be used as the preliminary tool for sustainability assessment - The values of the metrics documented in a Sus-VSM will not be sufficient to classify whether a specific metric is good or bad; this assessment requires comparing the values with either the performance in other similar lines/system
11	Dadashzadeh and Wharton (2012)	A Value Stream Approach for Greening The IT Department	-	- Same as traditional VSM added by 7 Green Wastes analysis: Energy, Water, Materials, Garbage, Transportation, Emissions and Biodiversity	- The Green Value Stream Mapping in conjunction with other practices as a systematic approach for greening The IT department
12	Folinas et al. (2014)	Greening the agrifood supply chain with lean thinking practices	- Water used - Energy consumption	- Selection of a product family - Current state mapping - Future state mapping - Defining a working plan - Achieving the working plan	-
13	Kurdve et al. (2011)	Use of environmental value stream mapping and environmental loss analysis in lean manufacturing work at Volvo	- VA (Value added) - NVAA (necessary-non-value-adding time)	- Current state - One (or several) possible future state are calculated and analyzed	-

(continued)

Table 1 (continued)

#	Author	Title	Environmental Indicators	Methods	Results/ Conclusion
			- NVA (non-value-adding time)		
14	Darmawan et al. (2014)	Value chain analysis for green productivity improvement in the natural rubber supply chain: a case study	- Energy (kWh) - Water (liter) - Material (kg) - Garbage (kg) - Transportation (km) - Emission (tones CO_2/day) - Biodiversity (Ha)	- Same as traditional VSM added by 7 Green Wastes analysis: Energy, Water, Materials, Garbage, Transportation, Emissions and Biodiversity - Actual State, Indicators Generating and Future State	- Increased the productivity of the company three times, maintaining the level of wastes
15	Paju et al. (2010)	Framework and Indicators for a sustainable manufacturing mapping methodology	- Energy (kWh) - Material (kg) - Emission (kg) - Water (kg) - Garbage (kg) - Costs ($) - Work absence days (d)	- Set goals and scope - Choosing the right indicators - Build SMM Model on computer (eVSM Software)	- SMM is based on VSM mapping tool
16	Torres and Gati (2009)	Environmental Value Stream Mapping (EVSM) as Sustainability Management Tool	- Water used (L) - Effluents (L) - Costs ($)	- Manufacturing process overview - Build VSM - Improvements - Verify Results	- Discovered the internal process with biggest losses - Some causes and some solutions were found
17	Rosenbaum et al. (2013)	Improving Environmental and Production Performance in Construction Projects Using Value-Stream Mapping: Case Study	- Material Wastes (kg/consumed) - Fuel Waste (liters/consumed)	- Preliminary Decisions; - Data collection; - Data Processing; - Current State map; - Analyze and Diagnosis;	- This methodology will allow construction managers to efficiently identify and measure waste sources - The full potential of the VSM tool was not realized in this research

(continued)

Table 1 (continued)

#	Author	Title	Environmental Indicators	Methods	Results/ Conclusion
			- Landfill disposal (%)	- Future State map; - Recommendations	(emissions, carbon footprint, incorporation of the social dimension)
18	Roosen et al. (2013)	Environmentally Lean Production: The Development and Incorporation of an Environmental Impact Index into Value Stream Mapping	- Environmental Impact Index (EII)	- Developing indicator - Identifying Kaizen Opportunities - Current State Environmental VSM	- The author emphasizes a new method, a new indicator for measuring environmental wastes - Practitioners have now a method for waste identification - Senior management can turn ISO 14001 objectives as the Industrial objectives
19	Vinodh et al. (2016)	Life cycle assessment integrated value stream mapping framework to ensure sustainable manufacturing: a case study	- Energy (Kwh) - Raw Material consumption (kg) - Ergonomic assessment of employees—PLI	- VSM drawing - Indicators calculate - Improvements - Future State	- The created model need to be expanded in varied manufacturing environments

fundamentals, principles, and tools. The studied organization improved both operational efficiency and environmental performance, so the STVSM tool is an effective approach to improve road transport operations.

Vinodh et al. (2016) integrated VSM and LCA which includes environmental impacts and cost dimensions in evaluating sustainability. Verrier et al. (2016) conclude that VSM with sustainable aspects needs to be one of the pillars of lean and green sustainable deployment.

The research and the analysis about VSM with environmental aspects shows a great portion of the references that try some methodologies involving lean and green aspects and the search for waste elimination.

The pursuit of lean and environmental wastes is an important pillar for companies that desire to implement lean and green philosophy. Some remarks about how these methodologies are structured can be seen in Fig. 3: (i) Methods of Deployment, (ii) Connection with other methodologies/policies, (iii) Established Indicators, (iv) Practitioners trained, and (v) Employee Involvement.

There are some methods for applying the VSM with environmental aspects, and this research examines the papers with higher impacts, but it is not the intention of this paper to test all methodologies and determine the best one. Some of the better methodologies are structured like current state drawings, indicators calculating, improvement execution, and defining future states.

One conclusion that should be noted from the various methodologies is that the most used and commonly cited is the Environmental Toolkit (EPA 2007). The more popular texts are by Faulkner and Badurdeen (2014) with S-VSM, Wills (2009) with environmental VSM, Vinodh et al. (2016) with an integrated model LCA and VSM, Paju et al. (2010) with SMM, White and James (2014) with Pmapping with environmental aspects, and Garza-Reyes et al. (2016) with a specific methodology for transportation sector STVSM.

The establishment of indicators is very critical for the mapping process. There is not a standard in place for the use of some indicators, but they are employed in almost all reviews. Some indicators are very difficult to measure due to technical aspects. For example, calculating the energy consumption of equipment of a process is difficult to determine because individual machines have different demands. The main indicators for mapping process are: (i) Energy Consumption (kwh), (ii) Water consumption (kg or liters), (iii) Raw material Consumption (kg), (iv) Emissions (kg or kg CO^2), and (v) Garbage/Waste (kg).

It is necessary that the experiences and practices of specialists of this theme should be encouraged within companies, marketplaces, and universities. That step will facilitate the evolution of the methodology through the knowledge evolution, and may help advance practices due to the lack of standardization of symbols, tools, and methods.

VSM is part of an organizational strategy for involvement of employees and its efficiency is based on a strong connection between top-down and bottom-up management. The involvement of employees is particularly important on a mapping process; if employees feel involved, they will help to identify waste. Organizations should facilitate this process.

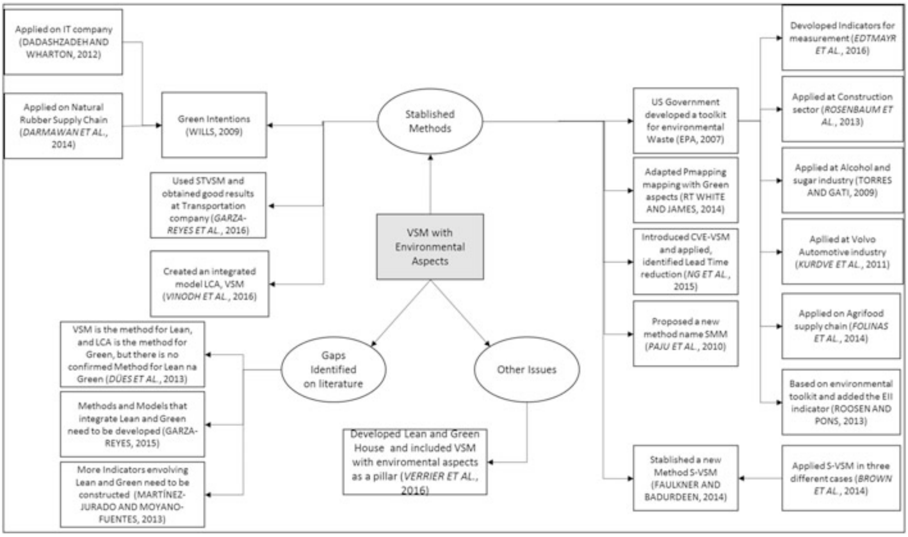

Fig. 3 Framework of Relationship from VSM with environmental aspects

Only a few cases from the literature seek a deeper approach to show the improvements and benefits by applying the methodology of Sustainable VSM. Technically, the use of a mapping tool does not create an improvement by itself. The involvement of employees, the objectives of the sponsors, and the creation of an autonomous team empowered with enough knowledge are important factors to change the scenario and pursue the future state of VSM.

4 Conclusions

Although this theme is relatively fresh, few cases have been applied to industry and services companies. This research locates the applicability of Sustainable VSM on the automotive industry, on small-sized manufacturing industries, the transportation sector, chemical, IT, agrifood, rubber supply chain, alcohol and sugar industry, and the construction sector. The application on case studies needs to grow and to show the technical improvements and the main benefits of using VSM with environmental aspects.

Further studies need to be pursued and proven by the lean and green scientific community. There are many opportunities to use lean and green tools for mapping and instituting improvements. The definition of some metrics, visual symbols, and the details for all sectors need to be consolidated.

It is important that future research include the application of lean and green practices and to consider VSM with environmental aspects. The majority of research on this theme does not utilize any kind of official mapping tool, but relies on improvements based on the knowledge of the authors or company specialists.

The environmental VSM tool resembles the Lean Tool Value Stream Mapping (VSM). The practitioners of lean manufacturing need to add environmental tools to their research and to eliminate company wastes. The use of this expanded tool can help companies reach environmental goals, desires, and needs. The practice of this tool can lead to a better company, which, in turn, will result in a better impact on society.

References

Brown, A., Amundson, J., & Badurdeen, F. (2014). Sustainable value stream mapping (Sus-VSM) in different manufacturing system configurations: Application case studies. *Journal of Cleaner Production, 85,* 164–179.

Dadashzadeh, M. D., & Wharton, T. J. (2012). A value stream approach for greening the IT department. *International Journal of Management & Information Systems (Online), 16*(2), 125.

Darmawan, M. A., Putra, M. P. I. F., & Wiguna, B. (2014). Value chain analysis for green productivity improvement in the natural rubber supply chain: A case study. *Journal of Cleaner Production, 85,* 201–211.

Dües, C. M., Tan, K. H., & Lim, M. (2013). Green as the new Lean: How to use Lean practices as a catalyst to greening your supply chain. *Journal of Cleaner Production, 40,* 93–100.

Edtmayr, T., Sunk, A., & Sihn, W. (2016). An approach to integrate parameters and indicators of sustainability management into value stream mapping. *Procedia CIRP, 41,* 289–294.

Epa. (2007). The Lean and energy toolkit. In: *Energy* (p. 56). Washington, DC, USA.

Faulkner, W., & Badurdeen, F. (2014). Sustainable value stream mapping (Sus-VSM): Methodology to visualize and assess manufacturing sustainability performance. *Journal of Cleaner Production, 85,* 8–18.

Florida, R. (1996). Lean and green: The move to environmentally conscious manufacturing. *California Management Review, 39*(1), 80–105.

Folinas, D., Aidonis, D., Malindretos, G., Voulgarakis, N., & Triantafillou, D. (2014). Greening the agrifood supply chain with lean thinking practices. *International Journal of Agricultural Resources, Governance and Ecology, 10*(2), 129–145.

Garza-Reyes, J. A. (2015). Lean and green—A systematic review of the state of the art literature. *Journal of Cleaner Production, 102,* 18–29.

Garza-Reyes, J. A., Villarreal, B., Kumar, V., & Molina Ruiz, P. (2016). Lean and green in the transport and logistics sector—A case study of simultaneous deployment. *Production Planning & Control, 27*(15), 1221–1232.

Kurdve, M., Hanarp, P., Chen, X., Qiu, X., Zhang, Y., Stahre, J., et al. (2011, May). Use of environmental value stream mapping and environmental loss analysis in lean manufacturing work at Volvo. In *Proceedings of the 4th Swedish Production Symposium* (*SPSS11*) (pp. 3–5).

Martínez-Jurado, P. J., & Moyano-Fuentes, J. (2014). Lean management, supply chain management and sustainability: A literature review. *Journal of Cleaner Production, 85,* 134–150.

Ng, R., Low, J. S. C., & Song, B. (2015). Integrating and implementing Lean and Green practices based on proposition of carbon-value efficiency metric. *Journal of Cleaner Production, 95,* 242–255.

Norton, A. (2007). *Sustainable value stream mapping as a technique for analysing and reducing waste in the UK chilled food sector* (Doctoral dissertation, Ph.D. thesis). Centre for Environmental Policy, Imperial College, University of London, London.

Paju, M., Heilala, J., Hentula, M., Heikkilä, A., Johansson, B., Leong, S., & Lyons, K. (2010, December). Framework and indicators for a sustainable manufacturing mapping methodology. In *Simulation Conference* (*WSC*), *Proceedings of the 2010 Winter* (pp. 3411–3422). IEEE.

Roosen, T. J., & Pons, D. J. (2013). Environmentally lean production: The development and incorporation of an environmental impact index into value stream mapping. *Journal of Industrial Engineering*, 2013.

Rosenbaum, S., Toledo, M., & González, V. (2013). Improving environmental and production performance in construction projects using value-stream mapping: Case study. *Journal of Construction Engineering and Management, 140*(2), 04013045.

Torres, A. S., Jr., & Gati, A. M. (2009, August). Environmental value stream mapping (EVSM) as sustainability management tool. In *2009. PICMET 2009. Portland International Conference on Management of Engineering & Technology* (pp. 1689–1698). IEEE.

Verrier, B., Rose, B., & Caillaud, E. (2016). Lean and Green strategy: The Lean and Green House and maturity deployment model. *Journal of Cleaner Production, 116,* 150–156.

Villarreal, B. (2012). The transportation value stream map (TVSM). *European Journal of Industrial Engineering, 6*(2), 216–233.

Vinodh, S., Ruben, R. B., & Asokan, P. (2016). Life cycle assessment integrated value stream mapping framework to ensure sustainable manufacturing: A case study. *Clean Technologies and Environmental Policy, 18*(1), 279–295.

White, G. R. T., & James, P. (2014). Extension of process mapping to identify "green waste". *Benchmarking: An International Journal, 21*(5), 835–850.

Wills, B. (2009). *Green intentions*. New York, NY: Taylor & Francis Group Ltd., Productivity Press.

Yang, M. G. M., Hong, P., & Modi, S. B. (2011). Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms. *International Journal of Production Economics, 129*(2), 251–261.

Vaccine Cold Chain in Brazilian Health System: A Logistics Assessment

L. P. D. S. Souza, J. V. V. Vasques, T. A. Aguiar and R. Flexa

Abstract Vaccines are perishable products consisting of antigens that degrade and lose potency when exposed to temperatures outside the specification limits. The storage system and transport of vaccines is a recurring concern for several Brazilian and international organizations. These products should be well maintained throughout the cold chain, respecting rigorously its temperature limits determined by the manufacturer. Thus, this work aims to analyze the Brazilian vaccine cold chain, in order to understand the problems and suggest improvements. Main contributions of this research are: (i) information management improvement, in order to provide demand data accuracy; (ii) development of a demand forecast model, able to cover all the cold chain; (iii) routine vaccination schedule solution as a way of reducing multi-dose vaccines waste; (iv) new national distribution centers and (v) packaging improvements.

Keywords Cold chain · Vaccines · Logistics · Heath system

1 Introduction

Vaccines, or immunobiological products, are an effective way of preventing diseases. Its production is based on antigens that activates antibodies response, and it promotes human body protection against diseases (Gorgulho 2009).

L. P. D. S. Souza · J. V. V. Vasques · T. A. Aguiar · R. Flexa (✉)
Centro Federal de Educação Tecnológica Celso Suckow da Fonseca—CEFET-RJ,
Departamento de Engenharia de Produção, Rio de Janeiro, Brazil
e-mail: raquelflexa@yahoo.com

L. P. D. S. Souza
e-mail: lucasdurand21@gmail.com

J. V. V. Vasques
e-mail: jvictorvasques@gmail.com

T. A. Aguiar
e-mail: taa.engprod@gmail.com

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These antigens must be maintained in controlled storage and distribution condition, otherwise the vaccine may have its effectiveness affected or even be life-threatening. In storage and distribution condition, temperature control is one of the most important aspect that must be assured. This immunobiological products has to be in low and controlled temperatures, sometime under zero degree Celsius.

The Cold Chain deals with the structuration and operation of vaccine supply chain, by ensuring storage and distribution condition from the immunobiological producers until the final health center. If Cold Chain has a appropriate physical and organizational structure and its operation is guaranteed by specialized teams, the vaccine will probably be in perfect conditions for its use (Rocha 2001).

This paper objective is to evaluate Cold Chain in Brazilian Public Health System, thought a supply chain description and a discussion about its improvement main issues.

2 Method

Lacerda (2010) combines some research methodology concepts and proposes a research typology, based on (i) research nature (basic or applied); (ii) objective (descriptive, exploratory or explanatory); (iii) scientific method (deductive, inductive or hypothetical-deductive) and (iv) research approach (quantitative or qualitative).

The nature of this research can by classified as applied, since this paper aims to produce knowledge for practical application. The research objective can be characterized as exploratory, since this study allowed the authors to get acquainted to cold chain problems and then highlight its main issue for improvement.

Turning to scientific method, it's an inductive research. This study tries to build general arguments based on particular observation in vaccine supply chain. The research approach is qualitative and the main resource for data gathering, phenomena interpretation and attribution of meanings is the context environment.

Yin (2005) says that data gathering in case studies can be based on a variety of sources as documents, file records, interviews, direct observation, participant observation and physic artifacts. In this research, the authors decided for having semi structured interviews with cold chain professionals, operations direct observation and documental analysis.

3 Literature Review

3.1 Logistics

Logistics is a field of knowledge that deals with planning and control processes of material flow, equipment and information thought production and supply chain.

Some of Logistics main objectives are to optimize transportation times and to reduce production costs. Therefore, it can lead to operational and financial efficiency, providing competitive advantages for the companies (Ballou 2006; Christopher 2015; Dicken 2015).

Gaither and Frazier (2004) have a limited view of this concept and defines Logistics as material flow management in inbound processes, inside manufacturing plants and in outbound processes. The author highlight the importance of material flow management between supplier, manufacturer and clients because it can carry a large amount of logistics costs.

According to Christopher (2015), Logistics refers to the following processes: procurement strategic management, material handling and storage, final products handling, storage and distribution, information management, distribution and sales channels management. These processes aim to maximize business profitability through orders execution optimization.

Ballou (2006) appointed that Logistics concept arise from material handling, storage activities and integrated material flow management. He also underscores the relation between this activities and customer satisfaction, because these processes performance, in this case, affects directly client perception about the company.

3.2 *Vaccine Cold Chain*

Brazilian National Immunization Program (Programa Nacional de Imunizações—PNI) was instituted in 1973 and it's a country priority. Federal, State and Municipal Government are responsible for its execution. Program main goals are to control, eliminate and eradicate vaccine-preventable diseases, through immunization strategies developed in hierarchical and decentralized activities (Netto 2008). PNI is a governmental action that allows social inclusion as its covers Brazilian entire population, without any type of distinction (Ministry of Health 2013a).

Vaccines must be maintained under strict temperature conditions, since the manufacturing plant until its destination, the local health centers. This process form the "cold chain" or "cold network" (UNICEF 2017). For PNI, cold chain embraces vaccine storage, conservation, handling, distribution and transportation (Rocha 2001).

Cold Chain goal is to guarantee the preservation of vaccines physical e chemical characteristics through all the chain, in order to assure human immunization. Heat accelerates vaccine deterioration and, for that reason, the immunobiological products must have its temperature controlled in all chain levels: national, state, regional and municipal/local. Inappropriate handling or a defective equipment may stop refrigeration and may compromise vaccine quality and safety (Rocha 2001).

World Health Organization (2015) states that an adequate vaccine storage and distribution system must have these characteristics:

- Guarantee a continuous supply of vaccines, immunization supplies and materials for waste handling;
- Guarantee adequate storage for vaccines, immunization supplies and materials for waste handling;
- Minimize vaccine waste for deterioration or shelf-life time;
- Keep accurate inventory record;
- Rationalize storage sites and use of transportation vehicles;
- Guarantee a proper waste disposal for all materials used in cold chain;
- Monitor storage and distribution system performance;
- Provide information for vaccine demand forecast process.

According to World Health Organization (2002), the main decisions during the cold chain design are the centralization level and the number of sites that vaccines will have to be handled until its final use. This decision evolves political and organizational factors, geographic aspects (clime, distance between the sites), infrastructure (means of transportation, roads conditions) and populational density.

4 Results

4.1 Brazilian Cold Chain Description

According to Cold Chain Manual (Ministry of Health 2013b), cold chain structure is divided into five levels: national, state, regional, municipal and local. Each one has different responsibilities in this chain until vaccine destination. Additionally, this chain can be extended to vaccine manufacturers, in national sites (as Bio-maguinhos and Butantã Institute) and international sites (as Sanofi-Pasteur and GlaxoSmithKline).

In national level, there are three main players that deals with cold chain: PNI General Coordination, Health Surveillance Secretariat and Ministry of Health. The main goals in this level is to provide logistic support for cold chain, to define operational guidelines and technical regulation, and also information management. It's also a national level responsibility the vaccines quality control and distribution for state level sites, through Immunobiological Storage and Distribution National Center—CENADI.

In state level, there are distribution center that are responsible for vaccine storage and distribution to regional and/or municipal sites. They also coordinate immunization schedules with Ministry of Health and, when requested, state health officers provide logistical, technical and educational support to regional and municipal institutions.

There are some Brazilian states that contain a large number of municipalities, as Minas Gerais and São Paulo, and, in these cases, state government decided for setting regional distribution centers. This solution intends to provide flexibility and agility in state level cold chain.

The municipal level responsibility is to distribute vaccines for local health centers, according to their demands. Almost every local health centers have vaccination rooms, where local technicians are responsible for keeping these products under controlled temperature and for immunizing patients.

4.2 Brazilian Cold Chain Main Issues

During direct observation and interviews, researchers realized that Brazilian cold chain main issues are:

- Lack of demand data record: local health centers don't log information as quantity of vaccine requested, quantity of stocked vaccine and quantity of applied vaccine doses in a structured way. In some cases, they logged this information for short periods and then erased and, in other cases, they had these records only in paper, with no digital records;
- Unstructured demand forecasting process: demand forecast process is empirically carried by local health center technicians. It's not unusual to face situation where there's vaccine stock outs and, in the other side, large stocked quantities. In this context, supply through the whole chain may be affected;
- Multi-dose vaccine waste: multi-dose vaccines have only few hours of shelf-life after having its vial opened. If a patient requires a vaccine that comes in a ten-dose vial and there's no other patients to have the other nine doses until the end of its opened-vial shelf-life, these nine doses will be wasted.
- Distance between Immunobiological Storage and Distribution National Center—CENADI—and state distribution centers: there's only one national center, placed in the city of Rio de Janeiro. Brazil has continental dimensions and cargo travel time can be long, even by plane, and the trip may have a lot of fight connections. It may compromise vaccine physical and chemical properties, since it's difficult to maintain temperature and humidity control through all the chain;
- Damaged diluent vials: PNI has a lot of lyophilized (freeze-dried) vaccines. These vaccines have to be mixed with a diluent in order to be applied. The diluents are primarily packaged in glass vials and these vials are thinner than vaccine vials. There's diluent waste as a result of vials breaks, therefore the vaccine can't be applied.

5 Discussion

The first proposition of this research is to structure a vaccine demand data record process. This proposition aims to provide a proper data logging for (i) vaccine requests, (ii) vaccines applied, (iii) quantities in stock and (iv) vaccine stock out. This four-information set allows healthcare managers to get to know real vaccine demand and understand main mistakes in local demand planning process. None the less, this information must be in digital format and centralized in an information system, so that managers can easily manipulate data.

Information quality control must be enforced among administrative and technical staff, in all chain levels, to make sure this process will provide accurate data to demand forecast process structuration, which is this work second proposition. There are epidemiological studies that focus on understanding diseases patterns and how vaccines can prevent disease occurrence. This research highlighted the importance of the construction of a mathematical model, based on epidemiological studies, to support demand forecast process trough cold chain. Researchers suggest this issue to be addressed for future studies.

The third issue to be discussed is multi-dose vaccine waste. A good practice that could be observed in some local health center is the routine vaccination schedule. Healthcare managers set a schedule for different vaccine application, for example, the patients only can be immunized against yellow fever on Mondays and Thursdays. This schedule drives demand for certain vaccines to specific weekdays, amplifying the chances of all doses contained in one vail to be actually applied in a patient, thereby causing waste reduction.

Problems caused by transportation between CENADI and state distribution centers can be treated by a future study about new national distribution centers opening. Nowadays, all the vaccines bought by Federal Government have to go to city of Rio de Janeiro and then addressed to state sites, in long flights, most of them with connection. A proper Supply Chain Design study must be developed, in order to evaluate alternative solutions, with different numbers of national distribution centers, different sites geographic localization, storage and transportation costs, transportation times, in context of available logistics infrastructure.

Diluent vails break is the last issue to be discussed in this research. One solution is to change diluent primary package to a synthetic material that presents important characteristics for this kind of chain, as resistance, non-toxicity, lightness and impermeability. Polyvinyl chloride (PVC) is vastly used in drug packaging, but this material adoption to biological products has to be tested.

6 Conclusions

This study aimed to evaluate vaccine cold chain in Brazilian Public Health System, and also make proposition for system improvement. Research first phase focused on literature reviews about general Logistics and Supply Chain management concepts. Then researchers worked on enhancing their knowledge about Brazilian National Immunization Program (Programa Nacional de Imunizações—PNI), Vaccine Cold Chain in Brazil and in international scope.

Although PNI is a world reference for its amplitude and coverage, study authors could realize that there are some problems that can addressed in order to provide cold chain improvements. These problems raised during interviews with cold chain managers and technicians, and also during direct observation. One of this research limits is that interviews and direct observation were made only in a manufacturer site, the national distribution center—CENADI—and two local health center.

Propositions highlighted the need of information management improvement, in order to provide demand data accuracy, and development of a demand forecast model, able to cover all the cold chain. This solution can reduce stock out risks, as well vaccine waste because self-life expiration. Routine vaccination schedule implementation is not a new practice in Brazilian Public Health System, but authors suggest that this practice would be implemented in all local health centers that deals with vaccination. It's an easy-implementation solution and a fast way to reduce multi-dose vaccines waste. This research also appointed the importance of a Supply Chain Design study, so that new national distribution centers can be evaluated according to its costs and logistics benefits. In order to treat diluent vails breaks, authors underscore evaluation of changes in packaging, to reduce waste and also preserving physical and chemical diluent properties.

These proposition implementations will provide better tools for healthcare managers decision making process and may increase cold chain efficiency, especially in a continental dimension country.

References

Ballou, R. H. (2006). *Gerenciamento da cadeia de suprimentos e logística empresarial* (5th ed.). Porto Alegre: Bookman.

Christopher, M. (2015). *Logística e gerenciamento da cadeia de suprimentos* (4th ed.). São Paulo: Cengage.

Dicken, P. (2015). *Global shift: Mapping the changing contours of the world economy* (7th ed.). London: Sage.

Gaither, N., & Frazier, G. (2004). *Administração da Produção e Operações* (8th ed.). São Paulo: Pioneira Thomson Learning.

Gorgulho, D. (2009). Rede de Frio. http://www.tecnocold.com.br/site/artigos/78-rede-de-frio.html?showall=&limitstart=. Cited November 17, 2015.

Lacerda, D. (2010). *O Planejamento Estratégico em instituições de ensino superior: compreendendo se e como as intenções transformam-se em ações estratégicas*. Rio de Janeiro: Tese de Doutorado em Engenharia de Produção—COPPE-UFRJ.

Ministry of Health. (2013a). *Programa Nacional de Imunizações: 40 anos*. Brasília, 2013. http://bvsms.saude.gov.br/bvs/publicacoes/programa_nacional_imunizacoes_pni40.pdf. Cited February 20, 2017.

Ministry of Health. (2013b). *Manual de rede de frio* (4th ed.). Brasília. http://pni.datasus.gov.br/Download/manual_rede_frio.pdf. Cited October 11, 2016.

Netto, G. C. (2008). *Contribuição para melhorar o gerenciamento logístico da cadeia de frio de imunobiológicos no Programa de Imunização do Brasil* (Dissertação de Mestrado em Transportes). Departamento de Engenharia Civil e Ambiental, Universidade de Brasília.

Rocha, C. M. V. (2001). *Manual de Rede de Frio* (3th ed.). Brasília: Ministério da Saúde. http://bvsms.saude.gov.br/bvs/publicacoes/manual_rede_frio.pdf. Cited February 17, 2017.

UNICEF. (2017). Cold chain and supplies. http://www.unicef.org/immunization/index_42071.html. Cited February 17, 2017.

World Health Organization. (2002). User's handbook for vaccine cold rooms and freezer rooms.

World Health Organization. (2015). The vaccine cold chain. http://www.who.int/immunization/documents/IIP2015_Module2.pdf. Cited February 17, 2017.

Yin, R. (2005). *Estudo de Caso: Planejamento e Métodos* (3ª edição). Editora Bookman.

The Impacts of Additive Manufacturing on Production Systems

**Douglas Rafael Veit, Daniel Pacheco Lacerda,
Maria Isabel Wolf Motta Morandi, Aline Dresch,
Luis Henrique Rodrigues and Pedro Nascimento de Lima**

Abstract Additive Manufacturing adoption has been growing in adoption in the last decades, holding the potential to fundamentally transform traditional production systems. Yet, its prospected impact on Production Systems and Operations Strategy is controversial. This article contributes to this debate by examining and summarizing the prospected impact of Additive Manufacturing on Production Systems, in the light of the Competitive Dimensions through a Systematic Literature Review. In particular, this paper organises this debate by highlighting the specific impacts prospected by the literature for each competitive dimension.

Keywords Additive manufacturing · Production systems · Competitive factors

1 Introduction

The Emerging Global Trends in Advanced Manufacturing (IDA 2012) identifies emerging trends in four technology areas, namely: Semiconductors, Advanced Materials, Additive Manufacturing and Biomanufacturing. Additive Manufacturing has been developed in the last 30 years (Mellor et al. 2014). By the late eighties, while universities and large industrial companies have started to use additive manufacturing, its equipment and materials costs were prohibitive, hampering application growth (Miller 2014). However, once used only for prototyping purposes, additive manufacturing started to grow its revenue share from products and services after the 2000s (Wray 2014). The Automotive, Medical, and Aerospace sectors are leading additive manufacturing adoption (Ford 2014). In 2014, industrial-grade 3D printers sales accounted for one-third the volume of industrial and robotic sales in the US (D'Aveni 2015).

D. R. Veit (✉) · D. P. Lacerda · M. I. W. M. Morandi · A. Dresch
L. H. Rodrigues · P. N. de Lima
GMAP | UNISINOS—Research Group on Modeling for Learning, UNISINOS Post-Graduate Program in Production Engineering, São Leopoldo, Brazil
e-mail: douglasveit@unisinos.br

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While Additive Manufacturing adoption has been growing in the last decades for other purposes than prototyping, its prospected impact on production systems and Operations Strategy is controversial. Regarding cost, for example, while some argue that this technology might only be beneficial to high-value products, others claim that it can help decrease costs reducing raw material waste. This paper aims to contribute to this debate by analyzing and summarizing the prospected impact of Additive Manufacturing on Production Systems, in the light of the Competitive Dimensions. To this purpose, this study employs a Systematic Literature Review of published papers that analyze Additive Manufacturing impact on Production Systems.

2 Background

Additive Manufacturing (AM) is a process of building parts based on a tri-dimensional model, layer by layer (Frazier 2014). While subtractive processes remove material from solid parts to manufacture products, additive manufacturing reduces waste by only using the materials needed to produce a product. Additive Manufacturing can also minimise inventory since parts can be produced using nearly just-in-time processes (IDA 2012). By producing parts via additive processes rather than subtractive ones, Additive Manufacturing allows for flexibility and customization, presents new digital supply-chain possibilities regarding product design and delivery, and contributes to sustainability by reducing material waste (IDA 2012).

Because of its properties, Additive Manufacturing may have the potential to fundamentally impact Production Systems, defined as the systems responsible for planning and controlling the flow of goods through the Manufacturing Systems (Antunes et al. 2008; Black 1998). Considering Additive Manufacturing's overwhelming impact in Production System, all companies in the impacted supply chains will need to review their Operations Strategy, and, as a consequence, how they will choose to compete (D'Aveni 2015).

Competitive factors, also known as Operations Strategy Performance Objectives, shape a company's position in the market and articulate market requirements to operations (Slack and Lewis 2010). These factors are considered by customers when making buying decisions (Skinner 1974), and can be defined as a cohesive set of criteria by which a company chooses to compete on the market (Miltenburg 2008). The most usual competitive factors in literature are Cost, Quality, Dependability, Flexibility, and Innovation (Antunes Jr. et al. 2014). Also, other dimensions are considered, such as speed (Dias and Fensterseifer 2005), and sustainability (Lira et al. 2015).

Table 1 Search results

Database	Entries retrieved	Selected titles	Selected abstracts	Selected papers
EBSCO Host	16.055	1.863	287	23
Scopus	16.512	2.052	384	49
Total	32.567	3.915	671	72

3 Methods

This paper employs a Systematic Literature Review, aiming to analyze and summarise knowledge already present in published papers, generating new knowledge. This review followed the recommendations for Systematic Literature Reviews (Morandi and Camargo 2015), and the following paragraphs discuss the relevant methodological decisions taken.

This review is characterized as configurative (Morandi and Camargo 2015), since it aims to explore the theme and does not impose a strict research question. As a consequence, this review used the broadly-used term "Additive Manufacturing". Scopus and EBSCO-HOST databases were queried, returning the number of entries listed in Table 1.

The papers found were further filtered, aiming to select only papers relevant to the research question. Papers with a technology focus were removed from the research corpus since they did not contribute to debate about the impacts of Additive Manufacturing on Production Systems. After this screening process, 72 papers were selected for further analysis.

A Categorical Content Analysis (Bardin 2011) was performed on the 72 selected papers, using Atlas Ti software. The analysis used the competitive factors mentioned earlier in this article as categories for coding, namely: Cost, Dependability, Speed, Flexibility, Quality, Sustainability and Innovation. The following section presents and discusses this analysis.

4 Analysis and Discussion

The benefits of Additive Manufacturing towards production costs has been disputed in the literature. 3D printing processes can be less productive than their traditional counterparts, thus increasing unitary costs (Pickett 2015). Also, 3D printing may require highly skilled labor (Bobb et al. 2012). Because of those reasons, Additive Manufacturing costs are still high compared to the injection-molding process (Berman 2012). These impacts are highlighted in the Table 2.

On the other hand, others have highlighted that AM can generate costs savings. When it comes to low-scale, custom-made products, AM can manufacture parts at lower unitary costs. Unlike injection molding, which requires expensive tools for every new product geometry, AM produces a broad mix of goods with fewer costs on tooling. Also, by reducing inventories, AM contributes to fewer logistics and storage space costs (Salles and Gyi 2013). Also, AM consumes less energy when compared to other processes, contributing to cost decrease (Shulman et al. 2012; Ford 2014). Furthermore, AM contributes to cost reduction by decreasing raw material waste by up to 70% (Stratfor Geopolitical Diary 2013). On top of that, AM can decrease costs by eliminating assembling. GE, for example, is now printing fuel nozzles of some jet engines. By using 3D printing, GE can fabricate this part in one piece, instead of assembling 20 different parts as it did before, cutting manufacturing cost by 75% (D'Aveni 2015) (Table 2).

When it comes to Dependability, there is agreement that AM can be an enabler by shrinking the supply chain (Ford 2014). Volvo, for instance, has experienced a 94% reduction in delivery time of parts manufactured with AM (Farish 2015). Shorter delivery times, in turn, lead to less overall delivery time variance and higher dependability. Also, with a shorter supply chain, finished parts inventory can be reduced (Stratfor Geopolitical Diary 2013).

Table 2 Impacts of additive manufacturing on production systems by competitive factor

Competitive factor	Impacts	Authors
Cost	Cost increase: High-cost machinery Productivity loss High cost of material and high skilled labor	Pickett (2015), Berman (2012), Bobb et al. (2012)
	Cost decrease: Reduces custom-made products costs Fewer costs on tooling Production straight from the CAD design Less raw material waste Less energy consumption Reduces assembling costs	Prince (2014), Salles and Gyi (2013), Shulman et al. (2012), Ford (2014)
Dependability	Shortens the supply chain Simplifies supply chain management Inventory reduction	Ford (2014), Stratfor Geopolitical Diary (2013), Farish (2015)
Speed	Enables the supply of low volume parts, maintaining low inventories Delivery time reduction Reduces market response time	Ford (2014), Berman (2012)

(continued)

Table 2 (continued)

Competitive factor	Impacts	Authors
Flexibility	Enables economic manufacturing of customized parts Reduces setup time Allows production of parts with complex geometry and different materials	Pickett (2015), D'Aveni (2015), Berman (2012), Salles and Gyi (2013), Petrick and Simpson (2013)
Quality	Results in lower accuracy and poorer finishing surface than other processes Grants low repeatability	Ford (2014), Berman (2012), Mahamood et al. (2014), Long et al. (2017), Mishra (2013)
Sustainability	Minimizes waste production Consumes less energy Results in a lower carbon footprint	Ford (2014), Le Bourhis et al. (2013), Frazier (2014)
Innovation	Fosters agile innovation processes with fast prototyping Enhances cooperation among designers and users Allows complex products manufacturing	Ford (2014), Berman (2012), Gardiner (2015), Salles and Gyi (2013), Tuomi et al. (2014)

AM contribution to companies striving to compete on speed is twofold. First, AM allows companies to shorten the product design cycle. Since there is no need for building machine tools in every new product, the design time can be significantly reduced (Ford 2014). Secondly, by shortening the supply chain, AM also contributes to companies seeking to compete on speed. Unlike other technologies, AM enables fast low-volume parts production, maintaining low inventories. With a fast design and production cycle, market response time can decrease (Berman 2012).

Because manufacturing products layer by layer allows for limitless customization and designs of greater intricacy (D'Aveni 2015), manufacturers can increase their production mix economically (Berman 2012). Furthermore, Additive manufacturing not only allows for complex product geometry but also permits the use of a diverse set of materials (wood, polymers, ceramic and metals) (Pickett 2015). While traditional processes subject to a wide production mix suffer from high setup times, AM can be flexible, yet with low setup time (Salles and Gyi 2013).

For those reasons, Additive Manufacturing contributes significantly to a Production System's Flexibility, allowing manufacturers to move from mass production to mass customization (Ford 2014). Ford Motor Company and BMW already permit customers to customize a set of their cars features, which will then be 3D printed (Ford 2014). In summary, AM can replace the competitive dynamics of large scale production with unitary production (Petrick and Simpson 2013).

Quality, however, seems to hamper AM's adoption. Currently, available technology is not precise or robust enough to most commercial products (Mishra 2013).

Specifically, additively produced parts have poorer accuracy and surface finishing compared to parts produced by traditional methods (Berman 2012). Furthermore, the fact 3D printed parts suffer from lack of repeatability is another drawback accounting against AM. The same design manufactured on different machines can vary significantly in form and physical properties (Ford 2014). Furthermore, there are fundamental trade-offs involving product size, accuracy, and speed (e.g., if one tries to print a large part fast, accuracy will suffer) (Ford 2014).

Sustainability, in turn, can be enhanced by Additive Manufacturing. AM can attenuate the environmental impact of traditional manufacturing processes that require more energy and generate more waste (Ford 2014). Additive Manufacturing processes are relatively cleaner than other processes (Le Bourhis et al. 2013), resulting in a lower carbon footprint (Frazier 2014; Le Bourhis et al. 2013).

Finally, AM accelerates the innovation process. Faster prototyping fosters agile innovation processes, reducing new product development time and costs (Berman 2012). Higher levels of product complexity do not add significant production costs, allowing companies to manufacture previously unviable products (Ford 2014). Also, AM facilitates outsourcing and sharing of designs among users, designers, and manufacturers, fostering fast, collaborative innovation processes (Berman 2012).

5 Conclusion

This paper identified Additive Manufacturing prospected impacts on Production Systems, regarding each competitive dimension. In summary, AM brings significant impacts on Production Systems targeted to custom-made products. AM brings the unprecedented possibility of engineering a Production System that features mass customization directly integrated from design to final product with minimal setup. Therefore, companies aiming to compete on Flexibility, Speed, Dependability, Innovation, and Sustainability can leverage on the rise of Additive Manufacturing. As a consequence, businesses that already compete by those factors should be aware of AM's impact on their industry and assess the need to adjust their operational strategy accordingly. Conversely, if quality (specially relating to surface finishing and repeatability) is paramount for a given market, as long as AM technology does not keep up with the market constraints, companies have reason to be skeptical about AM's impact. Also, if the company mix is strict, its volume is large requiring few setups and there is no need for customization, AM may have little to contribute to cost reduction.

References

Antunes, J. A. V., et al. (2008). *Sistemas de Produção: Conceitos e práticas para projeto e gestão da produção enxuta*. Porto Alegre: Bookman.

Antunes, J. A. V., Jr., et al. (2014). *Estratégia de Produção—20 Artigos Clássicos Para Aumentar A Competitividade da Empresa*. Porto Alegre: Bookman.

Bardin, L. (2011). *Análise de conteúdo*.

Berman, B. (2012). 3-D printing: The new industrial revolution. *Business Horizons, 55*(2), 155–162.

Black, J. T. (1998). *O projeto da fábrica com futuro*. Porto Alegre: Bookman.

Bobb, L. M., Shapiro, S., & Harris, P. (2012). The productivity paradox: A philosophical analysis and its impact in management. *Global Conference on Business & Finance Proceedings, 7*(2), 33. Institute for Business & Finance Research.

D'Aveni, R. (2015). The 3-D printing revolution. *Harvard Business Review, 93*(5), 40–48. Harvard Business School Publication Corp.

Dias, M. F. P., & Fensterseifer, J. E. (2005). Critérios Competitivos de operações agroindustriais: um estudo de caso na indústria arrozeira. *Revista Eletrônica de Administração, 11*(3).

Farish, M. (2015). A new dimension. *Automotive Manufacturing Solutions, 16*(4), 58–59. Ultima Media.

Ford, S. L. N. (2014). Additive manufacturing technology: Potential implications for U.S. manufacturing competitiveness. *Journal of International Commerce & Economics,* 1–35. U.S. International Trade Commission, Office of Industries.

Frazier, W. (2014). Metal additive manufacturing: A review. *Journal of Materials Engineering & Performance, 23*(6), 1917–1928. Springer Science & Business Media B.V.

Gardiner, G. (2015). 3D printing: Niche or next step to manufacturing on demand? *Composites Technology, 1*(5), 42–47. Gardner Publications, Inc.

IDA. (2012). *Emerging global trends in advanced manufacturing*. Alexandria: Institute for Defense Analyses.

Le Bourhis, F., et al. (2013). Sustainable manufacturing: Evaluation and modeling of environmental impacts in additive manufacturing. *International Journal of Advanced Manufacturing Technology, 69*(9–12), 1927–1939. Springer Science & Business Media B.V.

Lira, A. C. de Q., Gomes, M. de L. B., & Cavalcanti, V. Y. S. de L. (2015). Modelo de alinhamento estratégico de produção—MAP : contribuição teórica para a área de estratégia de produção. 416–427. https://doi.org/10.1590/0103-6513.069911.

Long, Y., et al. (2017). 3D printing technology and its impact on Chinese manufacturing. *International Journal of Production Research, 7543*(January), 1–10. Taylor & Francis. https://doi.org/10.1080/00207543.2017.1280196.

Mahamood, R. M., et al. (2014). Revolutionary additive manufacturing: An overview. *Lasers in Engineering (Old City Publishing), 27*(3/4), 161–178. Old City Publishing, Inc.

Mellor, S., Hao, L., & Zhang, D. (2014). Additive manufacturing: A framework for implementation. *International Journal of Production Economics, 149,* 194–201.

Miller, R. (2014). Additive manufacturing (3D printing): Past, present and future. *Industrial Heating, 82*(5), 39–43. BNP Media.

Miltenburg, J. (2008). Setting manufacturing strategy for a factory-within-a-factory. *International Journal of Production Economics, 113*(1), 307–323. https://doi.org/10.1016/j.ijpe.2007.09.001.

Mishra, S. (2013). Helping additive manufacturing "learn". *Metal Powder Report, 68*(4), 38–39.

Morandi, M. I. W. M., & Camargo, L. F. R. (2015). Systematic literature review. In A. Dresch, D. P. Lacerda, & J. A. V. Antunes Jr. (Eds.), *Design science research a method for science and technology advancement* (p. 161). London: Springer. https://doi.org/10.1007/978-3-319-07374-3.

Petrick, I. J., & Simpson, T. W. (2013). 3D printing disrupts manufacturing. *Research Technology Management, 56*(6), 12–16. Industrial Research Institute, Inc.

Pickett, L. (2015). 3-D printing: The new normal. *Appliance Design, 63*(2), 18–21. BNP Media.

Prince, J. D. (2014). 3D printing: An industrial revolution. *Journal of Electronic Resources in Medical Libraries, 11*(1), 39–45. Taylor & Francis Ltd.

Salles, A. S., & Gyi, D. E. (2013). Delivering personalised insoles to the high street using additive manufacturing. *International Journal of Computer Integrated Manufacturing, 26*(5), 386–400. Taylor & Francis Ltd.

Shulman, H., Spradling, D., & Hoag, C. (2012). Introduction to additive manufacturing. *Ceramic Industry, 162*(12), 15–19. BNP Media.

Skinner, W. (1974). The focused factory. *Harvard Business Review, 1*(May–June), 113–122.

Slack, N., & Lewis, M. (2010). *Operations strategy*. Financial Times/Prentice Hall. https://doi.org/10.1017/cbo9781107415324.004.

Stratfor Geopolitical Diary. (2013). Will additive manufacturing replace conventional manufacturing? *Stratfor Geopolitical Diary*. Stratfor, p. 20.

Tuomi, J., et al. (2014). A novel classification and online platform for planning and documentation of medical applications of additive manufacturing. *Surgical Innovation, 21*(6), 553–559. Aalto University, Department of Engineering Design and Production, School of Engineering, Aalto, Espoo, Finland: Sage Publications. https://doi.org/10.1177/1553350614524838.

Wray, P. (2014). Additive manufacturing–Turning manufacturing inside out (Cover story). *American Ceramic Society Bulletin, 93*(3), 17–23. American Ceramic Society.

Timetable Planning in a Courier Network: A Heuristic Resolution Method

E. Parra

Abstract A heuristic method is presented to solve the problem of timetable planning in a courier network. In a problem involving goods transport by routes on a network, the departure, transshipment and arrival times must be obtained for each node on the network. Transportation is via several types of transport vehicles with different capacities (generally multimodal). The vehicles must comply with a timetable that guarantees the connections at the points of transshipment while simultaneously ensuring that the greatest amount of merchandise is collected at each node. This problem can be generalized for other transport networks with transshipment stations for passengers or goods.

Keywords Courier · Timetable scheduling · Optimization models

1 Introduction

The vehicle routing and scheduling problem (VRP) has been–and continues to be studied in its different variants, as in the recent work by Alvarez and Munari (2017), including both traditional (Bodin et al. 1983) and more recent surveys (Drexl 2012). There are also excellent collective works such as that of Toth and Vigo (2014). Of course, works on classical combinatorial optimization include dedicated chapters: Nemhauser (1999), Ball et al. (1995) and Cook et al. (1998), as well as general logistic books (Kasilingam 1998; Ballou et al. 2007).

E. Parra (✉)
Department of Economics, University of Alcala, Madrid, Spain
e-mail: enrique.parra@uah.es

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1.1 Model Description

This paper presents a practical method with a short computation time for calculating timetables for postal and courier companies. These kinds of companies have several centers for collecting goods (or letters), and must make shipments between all the possible points on their network. The shipments are routed from one node to another via a transport network that includes several transshipment centers. These centers are considered to have costs and some transshipment capacity. The transport network is organized in routes that run through a series of network nodes, so the possibility of any source/destination (S/D) pair is guaranteed.

Transportation is done in transport vehicles, such as trucks of various types that differ in capacity and cost. These vehicles must comply with a schedule that guarantees the connections while allowing the largest quantity of merchandise to be collected at each node, and with the latest possible departure time that still enables them to meet their commitments.

1.2 Solution Approaches

This type of problem has two main sub-problems:

- (A) Optimization of trucks and schedules: given the network and routes, the goal is to find the vehicles' timetable on each route that will achieve an optimal schedule.
- (B) Route design: when the network nodes and their connections through the network (i.e. the road) are known, and considering other nodes that are not included in the initial routes, the problem is to choose the best location for the transshipment points to minimize transportation costs.

The method that solves sub-problem A can be used to "simulate" different scenarios for sub-problem B by changing the predefined paths.

In general terms, and using both approaches, the problem can be summarized as follows: given a network (with n nodes and m arcs connecting nodes), the aim is to determine how many trucks (and at what times) must circulate through each arc of the network to satisfy the source/destination (S/D) with minimum transport and transshipment costs.

A preliminary approach is developed using a heuristic method to solve the problem of calculating the schedules (for one vehicle per arc) to ensure that the vehicles delay their time of departure until as late as possible.

2 Proposed Resolution Method

2.1 Phases

The approach presented in this paper consists of three resolution phases encoded in computer software to test their practical feasibility. A strategy that isolates each sub-problem and solves them sequentially can make it feasible to solve sub problem (A).

The three phases are as follows:

(I) From a known network (nodes/arcs), an exact algorithm is used to calculate the optimal route for each source/destination pair (S/D).

(II) Once the optimal route of each S/D pair is known, the shipments in each arc are aggregated (for each arc that will transit several S/D pairs). We therefore know the transport needs between nodes, the occupation of a route, and the cost of the transshipments. If the transshipment capacity of one node is insufficient, it will be necessary to recalculate phase I.

(III) Finally, using the results from phase II, the problem to be solved is to determine the departure and arrival times at each node to minimize the weighted sum of waiting times in transshipments. This is done by formulating a linear programming problem solved with commercial optimization software. The result is a detailed list of departure and arrival times at each node.

This method allows all kinds of changes to be made in the inputs–such as costs and routes, among others–, and serves as a first stage in the aforementioned approach (B) for designing routes by simulating scenarios. However, for an optimal route design, a minimum spanning tree calculation algorithm (MST, see i.e. Nemhauser 1999) can be used as a first step to find the best route arrangement. If the routes have been decided previously, the process can be started in phase II.

A more detailed description is given below.

2.2 Phase I

The starting data of the problem are: nodes, possible arcs between them, the length of each arc in the network, and the speeds of the route. Shipments between each S/D pair are known and will be used in phase II.

The minimum time/cost paths between each S/D pair can be found from the network information using the Dijsktra algorithm (Dijsktra 1959) or any of its variants (Bazaraa et al. 1990; Cook et al.1998). When the optimal route algorithm ends, the output for each S/D is the arcs to be visited.

Another option is to make a previous calculation of the minimum spanning tree of the network, but this does not assure the minimum paths are being used from each pair of nodes.

2.3 Phase II

This phase considers the shipments to be made between each S/D pair, which can be aggregated for each arc on the network.

Different products (S/Ds) can therefore be assumed to be in transit in each arc, so the required transport volumes can be calculated in each arc on the optimal routes.

The solution can even be refined by an expert by deleting little-used arcs (although they maybe optimal for some S/Ds) in order to obtain fewer real routes.

If optimal routes were not calculated in Phase I because there was a predefined route scheme, the procedure will start in Phase II.

2.4 Phase III

Once the different S/D pairs for transit through the network are known, the objective is to calculate the departure and arrival times at all the network nodes to obtain the planned transshipments, and the “products” (S/Ds) can be exchanged before starting travel in the next arc. The aim of this implementation is to find the weighted sum of waiting times in transshipments.

In order to obtain the schedules, the following linear programming problem is solved with any optimizer. Fourer (2015) is a recent survey of optimizers.

Model TR

Data

i $\in$ Nodes, j $\in$ Nodes, k$\in$ Nodes,
a$\in$ arcs, od$\in$ set of sources/destinations (S/D)
a(i,j) $\in$ arc from i to j, not all possibilities are allowed
a′(i,j) $\in$ arc from i to j
sd $\in$ E (S/D with non-zero shipments)
sd′ $\in$ E (S/D with non-zero shipments)
q(a): shipment quantities (S/D) on arc a
t(i,j): travel time from node I to node j
W_i: sum of quantities arriving at node i

Variables

DT(arc(i,j), sd)

is the departure time from node i to node j of "product" sd (each S/D), which is the general case; DT is usually the same for each sd in each arc. Then an "all together" constraint will be included

ST (arc(i,j), sd)

is the slack of the time constraint as described below.

Constraints

$$\begin{aligned} &\mathrm{DT}(\mathrm{a(i,j)},\ \mathrm{sd}) + \mathrm{t(i,j)} < \mathrm{DT}(\mathrm{a}'(\mathrm{j,k}), \mathrm{sd}), \\ &\quad \forall(\mathrm{i,j,k})/\mathrm{a(j,k)},\ \ \mathrm{a}'(\mathrm{j,k}) \in \mathrm{A},\ \ \forall \mathrm{sd} \in \mathrm{q(a)} \cap \mathrm{q(a')} \end{aligned} \tag{1}$$

$$\begin{aligned} &\mathrm{DT}(\mathrm{a(i,j)}, \mathrm{pp}) = \mathrm{DT}(\mathrm{a(i,j)}, \mathrm{sd}'), \\ &\quad \forall(\mathrm{i,j})/\mathrm{a}\ (\mathrm{i,j}) \in \mathrm{A},\ \ \forall \mathrm{sd} \in \mathrm{qq(a)},\ \ \forall \mathrm{sd}' \in \mathrm{qq(a)} \end{aligned} \tag{2}$$

Equation (1) sets the time conditions between one arc and the next for each incident arc at node j and each arc leaving node j and carrying an S/D (sd) shipment.

The second equation establishes the coincidence of departure times for all S/Ds that circulate through the arc: all together.

Equation 1 is reformulated to include slack (which will be the waiting time at the node) and is the basis of the objective function:

$$\begin{aligned} &-\mathrm{DT}(\mathrm{a(i,j)},\ \mathrm{sd}) + \mathrm{DT}(\mathrm{a}'(\mathrm{j,k}), \mathrm{sd}) + \mathrm{ST}(\mathrm{a(i,j)},\ \mathrm{a}'(\mathrm{j,k}),\ \mathrm{sd}) = \mathrm{t(i,j)} \\ &\quad \forall(\mathrm{i,j,k})/\mathrm{a(j,k)},\ \ \mathrm{a}'(\mathrm{j,k}) \in \mathrm{A},\ \ \forall \mathrm{sd} \in \mathrm{qq(a)} \cap \mathrm{qq(a')} \end{aligned} \tag{1'}$$

Objective function

The function to be minimized is the weighted sum of the waiting times in the network:

$$\begin{aligned} &\mathrm{Min} \sum \mathrm{Wi} \cdot \mathrm{ST}(\mathrm{a(i,j)},\ \mathrm{a}'(\mathrm{j,k}),\ \mathrm{sd}) \\ &\quad \forall(\mathrm{i,j,k})/\mathrm{a(i,j)},\ \ \mathrm{a}'(\mathrm{j,k}) \in \mathrm{A},\ \ \forall \mathrm{sd} \in \mathrm{qq(a)} \cap \mathrm{qq(a')} \end{aligned} \tag{3}$$

Equation (1′) will produce at most a number of equations equal to the product of (number of arcs) and (number of SD).

Not all arcs in the network are used, only those that are on some minimal path or in the minimum spanning tree.

This model assumes that all transport resources (i.e. trucks) are waiting for each other to be able to make all possible transshipments. Limit departure times from nodes can also be included (next software version).

In terms of size, a case featuring 100 nodes, 5 arcs per node (500 arcs) and an average of 4 S/D combinations running through each arc produces a linear program of 2000 equations and 500 (DT) + 2000 (ST) variables. This small linear program can be solved in seconds with today's computers and optimizers.

2.5 Example

An example with 7 nodes is used to illustrate the method.

Tables 1 and 2 show the travel times between nodes (only possible connections are shown) and the shipments to be made between nodes. A time of 100 (min) is therefore required to travel from node 1 to node 3. Figure 1 shows the departure times in each node to the different destinations nodes (figures beside the arrows). To simplify the figure, the transshipment times are assumed to be included in the travel times.

As the figure shows, the first departure (t = 0) is from node 1, and the latest arrival time also occurs at node 1 (t = 126 + 86 = 212). Transshipments are made at nodes 3, 4 and 5. Departure time from node 3 is at t = 86 (towards nodes 4 and 5) and at t = 126 for node 1. Departures from node 4 are t = 50 (to nodes 5 and 3) and t = 126 to node 2. Departures from node 5 are t = 66 (to nodes 3 and 4) and t = 110 (to nodes 6 and 7).

These departure times guarantee that all transshipments are made.

Table 1 Travel times

Travel time	1	2	3	4	5	6	7
1			100				
2				40			
3	100			40	20		
4		40	40		50		
5			20	50		50	30
6					50		
7					30		

Table 2 S/D shipments

Shipments	1	2	3	4	5	6	7
1	0	35	85	96	17	24	28
2	89	0	83	92	32	96	81
3	46	59	0	34	94	24	8
4	83	11	82	0	77	92	54
5	64	72	9	17	0	52	93
6	76	85	51	50	13	0	62
7	38	31	99	40	5	86	0

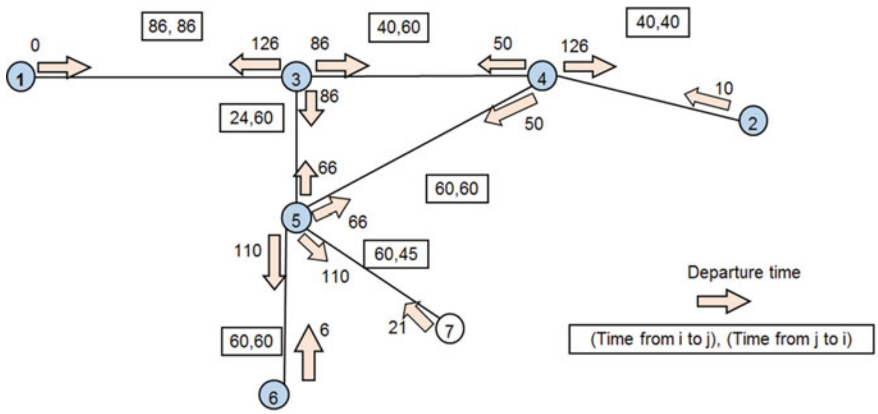

Fig. 1 Solution: departure times from each node (also travel times)

3 Conclusions

A method is presented to solve the timetable planning problem in a transport network. Starting with predefined routes found by the Dijsktra algorithm or by any other procedure, we proceed by aggregation to calculate the products (S/D shipments) that will transit through each arc of the network. Strategies can be applied at this point to eliminate little-used arcs. The timetable is then calculated using a linear programming model, which, although it may be large, can be solved very fast with current computer hardware and optimization software.

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References

Alvarez, A., & Munari, P. (2017). An exact hybrid method for the vehicle routing problem with time windows and multiple deliverymen. *Computers & Operations Research Volume 83*, 1–12 (consulted online).

Ball, et al. (1995). *Handbooks in operations research and management science, 8: Network Routing*. North-Holland.

Ballou, R. H, & Srivastava, S. K. (2007). *Business logistics/supply chain management* (5th ed). New Delhi: Pearson Education.

Bazaraa, M., et al. (1990). *Linear programming and network flows*. Hoboken: Wiley.

Bodin, L. D., Golden, B. L., Assad, A., & Ball, M. O. (1983). Routing and scheduling of vehicles and crews: The state of the art. *Computers & Operations Research, 10*(2), 67.

Cook, W., Cunningham, W., Pulleyblank, W., & Schrijver, A. (1998). *Combinatorial Optimization*. Hoboken: Wiley.

Drexl, M. (2012). Rich vehicle routing in theory and practice. *Logistics Research, 5*(1–2), 47–63. https://doi.org/10.1007/s12159-012-0080-2.

Fourer, R. (2015). Linear programming: Software survey. *OR MS Today INFORMS, 42,* 3.
Dijsktra, E. (1959). A note on two problems in connexion with graphs. *Numerische Mathematik*. pp 269–271.
Kasilingam, R. G. (1998) Logistics and transportation. Dordrecht: Kluwer.
Nemhauser, G., & Wolsey, L. (1999). *Integer and Combinatorial Optimization.* Hoboken: Wiley.
Toth, P., Vigo, D., (Eds.). (2014). Vehicle routing: Problems, methods, and applications, MOS-SIAM series on optimization. 2nd ed.

Disaster Management: Initiating Emergency Response for Forest Fires

S. Ozmehmet Tasan and Y. E. Ergenc

Abstract When a forest fire occurs, to cope with this disaster a range of facilities are needed. Although these facilities may be efficient, their usages should be coordinated according to the requirements needed for a particular forest fire. Initiating firefighting activities on time, especially arrival of fire water tender and the ground team onto fire areas in critical response time is crucial for effective fighting against forest fires. Additionally, when multiple fires occur during a dry season, the response planning, and coordination become vital to fighting fires. Therefore, emergency response planning/coordination gains paramount importance while firefighting. This study focuses on one of the most important aspect of the wildfire response phase: initial emergency response in fixed regional forest directorates and airports. In this study, a heuristic methodology is proposed to solve this problem with real map data by using Network Analyst toolbox under ArcGIS program, which is used to determine optimum route that minimize arrival time to forest fires. To show the applicability of the proposed methodology, forest fire data that was collected in Turkey is used.

Keywords Disaster management · Response planning · Forest fires Firefighting

1 Introduction

Disaster management is a repetitive process, which is often referred as disaster management cycle. For all of these reasons, government and societies should organize and plan their activities in disaster management cycle. Disaster management cycle divides into four phases: mitigation, preparedness, response and

S. Ozmehmet Tasan (✉)
Department of Industrial Engineering, Dokuz Eylul University, Izmir, Turkey
e-mail: seren.ozmehmet@deu.edu.tr

Y. E. Ergenc
Graduate School of Natural and Applied Sciences, Dokuz Eylul University, Izmir, Turkey

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recovery. Among these phases, response phase has gained importance in academic interest. According to Altay and Green (2006) who reviewed operations research and the management science research in disaster operation management, there is a need of research in this area and the 27% of the last published articles is related to response phase of the disaster management cycle. Response phase occurs after disaster strikes. To save lives as well as to minimize the damage to ecosystem and also properties, immediate response should be taken. The promptness of the response may also improve the effectiveness of recovery at the shortest possible time. Experts in this area states that following a natural disaster, the first 72 h are the most critical, since quick and punctual response with the use appropriate necessary resources can save the threatened lives of humans, animals, ecosystem etc. (Paul 2011). In the light of this, it can be clearly stated that the efficient planning/ coordination of initial response becomes crucial.

In the case of forest fires, successful forest fire management is partly about enabling authorities to react promptly and with certainty that resources consumed in a rescue will be recouped. This paper focuses on one of the most important aspect of the wildfire response phase: initial response (e.g. fire water-tender, manpower, firefighting airplane and helicopter) in fixed regional forest directorates and airports. The remainder of this paper is organized as follows. Section 2 gives brief information about forest fires and reviews the literature on response coordination/ planning for forest fires. In Sect. 3, the proposed methodology for initial response coordination was introduced together with inputs and model description. Section 4 includes the application of the proposed methodology for forest fires in Turkey, and particularly generates an initial response coordination plan for Osmaniye forest fire. Finally, concluding remarks are given in Sect. 5.

2 Forest Fires and Response Planning

Forests are an inseparable component of the ecosystems. Therefore, forest will continue to play a role in the future as in the past. Forest fires in the disaster area include damage of the forest's products and loss of objects of scientific, economic, or environmental value. The elements needed to reveal the fire are oxygen, heat, and fuel, which is often called fire triangle. If any element can be taken away, fire goes out or does not start. In history, for many countries, to achieve a quick and effective initial response to forest fire, the closest firefighting forces with the appropriate resources were coordinated.

From the academic point of view, recently, there are a few papers in literature that have studied initial response in forest fires from a more comprehensive point of view. Fiorucci et al. (2004) implied optimal relocation problem in Italian territory. The resources were water-bombers, heli-tanker, and a mix of single and light medium twins' helicopter. Forest fire hazard assessment presented topography, meteorological forecast, vegetation data and real time information. Wiitala and Wilson (2004) developed a stochastic simulation model for forest fire preparedness planning. The model is designed to closely represent the dynamics of fire occurrence and suppression. Ntaimo et al (2014) modeled a two-stage stochastic integer programming standard response model for initial attack. They relocated the resource units based on the 30 and 60 min maximum travel time restriction. There have been numerous papers discussing air resource management. Finney (2002) proposed an approach where the minimum travel time needed to reach the forest fire from the nodes is investigated. Haight and Fried (2007) developed a scenario-based standard response model while considering: the number of suppression resources deployed and the expected daily number of fires that do not receive a standard response as the two objective functions. The primary constraint is budget and also there is uncertainty about the number of fires, fire location and fire intensity (Mitsakis et al., 2014). Greulich (2008) designed a model which investigates the change in flight distance between random fire locations that is useful for reallocating the air tanker resource between fires.

Aktas et al. (2011) designed a model that organization of firefighters to access up to five minutes each zone and designed to be 100% of the coverage area in Istanbul. An integer programming model was established for this purpose, the data obtained geographical information system was resolved. Akay and Sakar (2009) used same examination for from 6 fire operations center of regional forest directorate to 6 fire areas using ArcGIS in Kahramanmaras. In order to perform effective response to forest fires, especially fires occurred in the first degree sensitive areas; first responders must reach in critical time (20 min) the area due to the higher possibility to control the fire. The area which can be reached by the first responders in 20 and 40 min was determined. In addition, Network 2001 program was used in order to determine the optimum route that provided access to the fire area in the minimum time. In the study, potential forest fire areas were chosen from the place where forest fires occurred between the years 1999–2009 in Kahramanmaras.

It can be clearly seen from the literature review that there is a little research in response planning for disaster management. Hence, there is less research focusing on response planning for forest fires. Moreover, the related literature deals with experimental case and small size real world problems. This study focuses on filling the research gap in this area where we considered forest fire initial response planning using real geographical data, road network and weather conditions.

3 Proposed Methodology for Initial Response Planning/Coordination to Forest Fires

In this study a heuristic model is proposed for coordinating the responses needed to suppress the forest fires in Turkey. The schematic representation of the structure of the forest fire initial response coordination model is illustrated in Fig. 1. The proposed model uses four types of input data related to resource, GIS, forest fire and condition. These data are processed by the proposed heuristic model and a forest

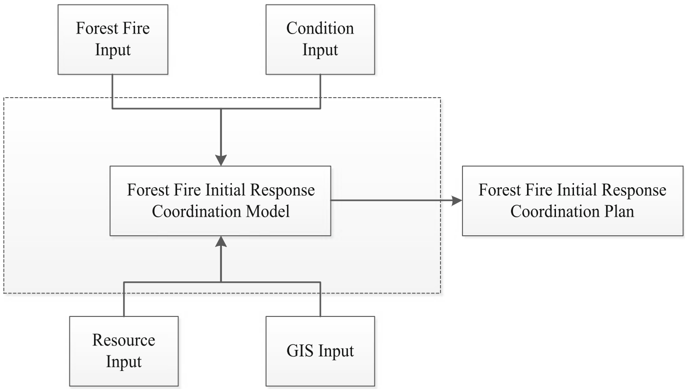

Fig. 1 Schematic structural representation of the proposed model

fire initial response coordination plan is generated. The methodology contains information about who will be going to interfere, which resources will be needed, how many resources will interfere, which road they will be using, and how long will it take to travel there.

The resources input consist of the land and air teams. They are located in different place. Fire water tender and the ground team are located in regional forest directorates. The aircraft teams charter by the forestry ministry to suppress the fire in summer season. The forest fires input consist of location of the fire, the distance of fire spread, the topography of the location. In order to generate GIS input, geographical information system was used to minimize the time interval to reach the fire location. Network Analyst Toolbox was used under ArcGIS 10.2.2. It generates a closest road between each facilities and incidents. Network cost was determined as the travel time. All data projected to WGS 1984 UTM_Zone 36 N. Speed limits were defined for different road type based on speed limitation. Additionally, meteorological conditions and parameters play a very important role on the occurrence, severity and duration of forest fires. Human-made and natural forest fires only occur when meteorological conditions are suitable. As condition inputs, humidity, wind speed and temperature data were used. Moreover, these conditions were used to identify classification of fire warning.

This initial response coordination model focuses on one of the most important aspect of the wildfire response phase: initial response (e.g. helicopter, aircraft, fire water-tender, manpower) in fixed regional forest directorates and airports. Model investigates the initial response one forest fire and at most three simultaneous forest fires. Land team (vehicles and manpower) have to reach the disaster in minimum time. For this purpose, a network model is produced in ArcGIS based on the real road map of Turkey. The network model aims at generating optimal routes for the minimizing the initial response time from regional forest directorates to the forest fires under ArcGIS by taking into account the road speeds which is determined by the General Directorate of Highways of Turkey. Heuristic model which is programmed by MATLAB R2013a is taken into account meteorological conditions (humidity, wind speed and temperature) of forest fires, minimum time to reach the fires from the regional forestry directorates and airports where the air teams are located. When a forest fires occurs in Aegean Coast especially in a peninsula and also the Taurus Mountains especially in a valley. These forest fires have suppression priority.

The overall procedure for the proposed methodology is outlined as follows;

---

procedure1: Proposed methodology
input: fire coordination data *CF*(*X_Coord*, *Y_Coord*), meteorological conditions (*humid*, *winds*, *temp*),
output: the best solution (the shortest initial response time)
begin

$t \leftarrow 0$;
categorize fire according to *humid*, *winds* and *temp*;
evaluate *MC* by forest fire weather category model routine;
//step 1: Land team planning
determine $CLT_d(X\_Coord, Y\_Coord)$ for all regional forest directorates
calculate distance times TDL_d from each $CLT_d(X\_Coord, Y\_Coord)$ to $CF(X\_Coord, Y\_Coord)$;
sort the distance times TDL_d in increasing order;
assign the land team with minimum TDL_d;
$LRT \leftarrow min(TDL_d)$
//step 2: Air team planning
if MC=3
 assign air team;
 determine $CAT_j(X\_Coord, Y\_Coord)$;
 calculate distance time TDA_j from $CAT_j(X\_Coord, Y\_Coord)$ to $CF(X\_Coord, Y\_Coord)$;
 sort the distance times TDA_j in increasing order;
 assign the air team with minimum TDA_j;
 $ART \leftarrow \min(TDA_j)$
evaluate fire initial response time *FIR* with minimum response time;
$FIR \leftarrow \min(LRT, ART)$
output the best solution *FIR*

end

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4 Application of the Proposed Methodology

4.1 Forest Fires in Turkey

Turkey with a surface area of approximately 80 million hectares has a rich diversity of mountain and eco-geography. Correspondingly ecological richness, its forest is rich in species and composition. Based on the between the years of 2005–2012 updated forest management plans, Turkey has 21,678,134 ha of forested area. According to this determination, the forest covers 27.6% of the country's surface area. Turkey is under threat of natural and human made forest fire. Indeed, not only socio-economic but also natural condition of Turkey causes this disaster. Especially, this disaster happens in coniferous forest in Turkey's Mediterranean and Aegean region along 5–6 months. In this context, forest fire happened 1978 times in Turkey between the years 1970–2012. At that time these records were confirmed as the highest number of natural disasters. Accordingly, 269 disaster as maximum number occurred in Antalya. In these forest fires, 283 people died, 90 people were injured and 964 people were influenced (Ozsahin, 2013).

In Turkey, a fire warning is issued after the watchtower has seen it. Basis of fire warning assessment divides into four categories by the Ministry of Forestry of Turkey. First category: When the fire warning is issued, if the humidity is over 60 (%), wind is between 1 and 5 km/h, temperature is 15–25 °C and fuel have all conditions, it is labeled as first category fire warning. Second category: When the fire warning is issued, if the humidity is 50–60(%), wind is 2–5 km/h; temperature is 20–30 °C. The forest is not continuous, and the fire does not threaten the residential areas, it is labelled as second category fire warning. Third category: When the fire warning is issued, if the humidity is 30–40(%), wind is 5–10 km/h, temperature is 30–35 °C and the forest does not continuous. If the area is in Eagan Coast especially in a peninsula and also the Taurus Mountains especially in a valley, it is labeled as third category fire warning. Fourth category: When the fire warning is issued in a critical area, if the humidity is less 25 (%), wind is 10 km/h or over 10 km/h. Temperature is over 35 °C. Forest is young, and fire threatens the residential areas.

In Turkey, there are 9 regional forest directorates; i.e. in Sakarya, Balikesir, Izmir, Sanliurfa, Artvin, Ankara, Kahramanmaras, Afyonkarahisar, Isparta and 14 airports where the air teams are located in Canakkale Center1 & Center2, Edirna-Kesanli, Bursa-Yenisehir, Yalova-Ciflikkoy, Kocaeli-Kartepe, Izmir-Selcuk, Menderes, Kemalpasa & Bergama, Manisa-Akhisar, Denizli-Center, Adana Saricam & Kozan.

4.2 Initial Response Coordination Plan for Osmaniye Forest Fire in Turkey

We have randomly selected a historical forest fire among Turkey's 39 big scale forest fires and then planned the initial response coordination for this forest fire. This forest fire started near Osmaniye in (36.275314, 37.051967) coordinates. The forest fire occurs under the following meteorological conditions, the fire is in danger of spreading and growth. The categorization of the meteorological conditions is essential to right suppress to the wildfire. During this forest fire, the meteorological conditions were recorded as follows: humidity was less 30%, wind was between 0 and 5 km/h (except 5) and temperature was over 35 °C. The GIS data was generated by ArcGIS. Turkey road map was achieved from Geofabrik that generated based on openstreet.com map database. All data projected to WGS 1984 UTM_Zone 36 N. Speed limits were defined for different road type based on speed limitation of Turkey. The proposed solution methodology is used to generate a initial response plan (see Table 1). According to the initial response plan found by the proposed model, it can be stated that Kahramanmaras land team and air teams which are located in Adana Kozan Airport should be used to suppress Osmaniye

Table 1 Initial response plan for Osmaniye forest fire

			Departure point	Departure time (min)	Travel time (min)	Arrival time (min)
Land team	1	Man power	Kahramanmaras	0	72.85	72.85
		Ground vehicle				
Air team	1	Aircraft (airplane)	Adana – Kozan	0	26.93	26.93
	2	Man power	Adana – Kozan	0	41.07	41.07

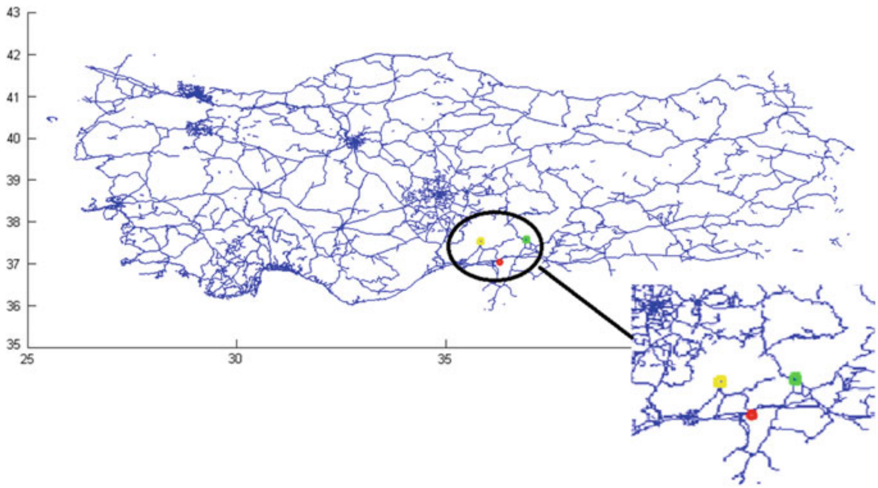

Fig. 2 Response location for one forest fire near Osmaniye

(1999) forest fire. In this solution, initial response time is approximately 27 min. Figure 2 illustrates the mapped solution found by proposed methodology, where fire location is represented by red circle; initial response teams assigned to this forest fire are represented by squares, i.e. land (green) and air (yellow).

5 Conclusion

Forest fires are not predictable events, but when it strikes will may damages the forest areas and endanger the settlements which is located the forests. It seems to be a need to cope with the forest fires. The main objective of forest fire management is to minimize the damage caused by forest. For this reason, in this study, response coordination for forest fire management is proposed in order to shorten the time of response when a fire occurs. The proposed response coordination approach is using Network Analyst Toolbox under ArcGIS software to determine the optimum route that minimizes the arrival time of the response team to forest fire location. Later, the approach is applied to coordinate the responses of potential forest fire zones in Turkey by considering 9 regional forest directorates of Turkey.

Forest fire initial response plan uses the historical 39 large-scale forest fires data which are humidity, wind speeds and temperature. The heuristic model propose initial attack from 9 regional forestry directorates and firefighting airplane and helicopter which are located in airports to the forest fires by considering priority areas and the meteorological conditions. Priority areas are Eagan Coast especially in a peninsula and also the Taurus Mountains especially in a valley.

There are still further works which can perform. Considerations can be given to reasonably consider evacuating the people which live endangered settlements where the forest fires occurs and reducing the uncertainty of the extinguish time with defining the real capacity of the resource units. The model can be regenerated for serving the all forest areas from the forest fire first responder stations and forestry operation directorates in Turkey.

References

Akay, A., Sakar, D. (2009). Yangın sahasına en kısa sürede ulaşımı sağlayan optimum güzergahın belirlenmesinde CBS tabanlı karar destekleme sisteminin kullanılması. In *TMMOB Coğrafi Bilgi Sistemleri Kongresi*

Aktas, E., Ozaydin, O., Ulengin, F., Onsel, S., & Agaran, B. (2011). İstanbul'da itfaiye istasyonu yerlerinin seçimi için yeni bir model. *Endüstri Mühendisliği Dergisi, 22*(4), 2–12.

Altay, N., & Green, W. G. (2006). OR/MS research in disaster operations management. *European Journal of Operational Research, 175,* 475–493.

Finney, M. A. (2002). Fire growth using minimum travel time methods. *Canadian Journal of Forest Research, 32*(8), 1420–1424.

Fiorucci, P., Gaetani, F., Minciard, R. (2004). An integrated system for the forest fires dynamic hazard assessment over a wide area. In *International Environmental Modelling and Software Society International Congress—Complexity and Integrated Resources Management*

Greulich, F. E. (2008). Modeling airtanker flight distance between concurrent fires: The development and use of statistical distribution parameters. *Forest Science, 54*(1), 47–57.

Haight, R. G., & Fried, J. S. (2007). Deploying wildland fire suppression resources with a scenario based standard response model. *Information Systems and Operational Research, 45*(1), 31–39.

Mitsakis, E., Stamos, I., Grau, J. M. S., & Aifadopoulou, G. (2014). Optimal allocation of emergency response services for managing disasters. *Disaster Prevention and Management, 23*(4), 329–342.

Ntaimo, L., Arrubla, J. A. G., Stripling, C., Young, J., & Spencer, T. (2014). A stochastic programming standard response model for wildfire initial attack planning. *Canadian Journal of Forest Research, 42*(6), 987–1001.

Ozşahin, E. (2013). Türkiye'de yaşanmış (1970–2012) doğal afetler üzerine bir değerlendirme. 2. In *Türkiye Deprem Mühendisliği ve Sismeloji Konferansı*

Paul, B. K. (2011). *Environmental hazards and disasters: Contexts, perspectives and management*. New York: Wiley.

Wiitala, M. R., Wilson, A. E. (2004). Wildfire initial response assessment system: A tool for fire preparedness. In *Proceedings of the Second International Symposium on Fire Economics, Planning and Policy: A Global View*, 19–22

State of the Art on Arduino and RFID

P. J. Soares, C. Oliveira, G. Morales, J. Arica and I. Matias

Abstract Although RFID has matured over the years, it still presents some drawbacks. One of its crucial limitations is its high cost implementation for most companies. In order to solve that, the open-source prototyping electronic platform, Arduino has been used worldwide. However, studies on the use of Arduino and RFID have been scarce yet. Hence, this paper aims to analyze the state of art on these technological tools so that other authors can use it in their papers review. The research was carried out through a structured literature review, in February 2017, using the database Scopus. As a result, it was obtained 59 papers, published from 2007 to 2016. Then, relevant papers, main countries, areas of application, and papers per year analyzed.

Keywords Bibliometrics · Open-source platform · Radio frequency identification

P. J. Soares (✉) · C. Oliveira · G. Morales · J. Arica
Production Engineering Laboratory (LEPROD), State University of Northern Rio de Janeiro (UENF), Campos dos Goytacazes, RJ 28035-200, Brazil
e-mail: patricksoares@pq.uenf.br

C. Oliveira
e-mail: cristianomo@pq.uenf.br

G. Morales
e-mail: gudelia@uenf.br

J. Arica
e-mail: arica@uenf.br

I. Matias
Department of Cepecam, UCAM, Av. Anita Peçanha, 100—Parque São Caetano, Campos dos Goytacazes 28030-335, Brazil
e-mail: italo@ucam-campos.br

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1 Introduction

Currently, humanity lives in a pace of technological development never seen in history. In this context, the Internet of Things (IoT) seeks a full connection between the real and virtual worlds (Aydos and Ferreira 2016).

The IoT is the combination of technologies such as Global Positioning Systems (GPS) and Radio Frequency Identification (RFID) (Aydos and Ferreira 2016) besides Micro and Macro electronic systems. IoT has been taking automation to the next level, enabling process optimization, device controlling with minimum human intervention, and better monitoring of large amount of data (Tommy et al. 2015). The RFID has been used for decades but only recently lower cost and increased capabilities made this technology viable (Manna et al. 2014).

The open source platform, Arduino, has been used to lower RFID costs. Its key features such as inexpensive, cross-platform, simple, clear programming environment, open source and extensible software and open source and extensible hardware, make it a good choice for IoT solutions as well (Sharma and Rani 2015).

However, studies on the use of these two integrated technologies are still scarce. Therefore, this paper aims to analyze the state of art on Arduino and RFID based on the adopted procedure by (Fahimnia et al. 2015) and Vaz et al. (2015).

This paper is structured as follows. First, it is approached some concepts on both Arduino and RFID (Sect. 2), following by its methodology (Sect. 3), main results (Sect. 4), and finally its conclusions (Sect. 5).

2 Concepts

RFID is an automatic identification technology without physical contact with the objects, based on the emission of radio signals (Aydos and Ferreira 2016), able to automatically monitor and track a person, objects, package, etc. (He et al. 2016).

This technology has two main components: the Interrogator (RFID Reader) which transmits and receives the signal and the Transponder (tag) attached to the object. RFID tags contain at least two parts, modulating and de-modulating a radio-frequency signal; and an antenna for receiving and transmitting the signal.

The RFID Reader emits a low-power radio wave field which is used to power up the tag so as to pass on any information that is contained on the chip (Kamaraj et al. 2016) (Fig. 1).

Recently, RFID has been used in many applications worldwide. The biggest difference between RFID and other recognition technology is that it can use electromagnetic waves for reading the tags. Moreover, it can simultaneously read multiple tags (Huang et al. 2015).

On the other hand, Arduino is an open-source tool used for developing computing devices that have sensing and controlling features, a lot more than a normal computer (Sharma and Rani 2015). It has a single-board microcontroller

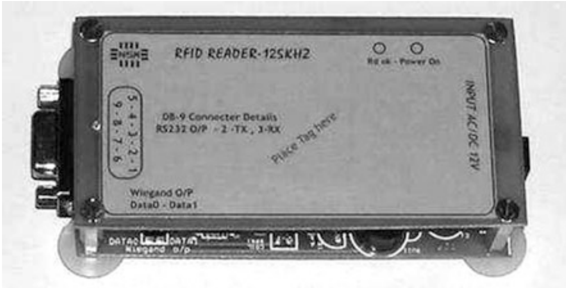

Fig. 1 RFID reader (Kamaraj et al. 2016)

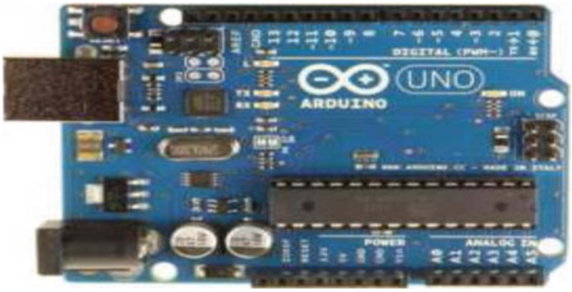

Fig. 2 Arduino board (Manna et al. 2014)

(shown in Fig. 2), and a development environment for writing software for the board (Huang et al. 2015; Sharma and Rani 2015). We can build interactive applications using Arduino. For example, it can take inputs from a variety of sources such as switches, sensors and control lights, motors and other physical outputs (Sharma and Rani 2015).

3 Methodology

This paper's methodology used the methods adopted by Vaz et al. (2015). Also, we refer to Fahimnia et al. (2015) to present a network analysis. Both of them used a systematic literature review. Likewise, the same database, Scopus was adopted, with the following keywords: "Arduino and RFID" which could be displayed on the title, abstract or keywords. The research was conducted, involving papers in any language, taking into consideration the entire time period of the base (by February 2017).

After that, bibliometric parameters were analyzed and then they were interpreted. LibreOffice Cal and R were used to handle prior data, and finally the graphs were plotted through VosViewer (2017) and R Core Team (2017).

This research turned out 59 papers, which were exported to the paper management software Zotero, where they went through a filtering process. The stages of

Table 1 Stages that comprise the paper selection process and their results

Stages	Filters	Results
1 Keywords selection	"Arduino" and "RFID"	–
2 Database selection	Scopus	–
3 Searching for papers in databases keywords	–	59
4 Excluding papers that were not related to this paper aim	–	47
5 Selection of papers for full reading	–	47

Source (Adapted by Vaz et al. (2015))

this process and their respective results are shown in Table 1. By analysing this table, we note that 12 papers were excluded once they were not related to this paper aim.

4 Results

As the main results from this research, a summary of its quantitative data was obtained. With that, it was first analyzed the chronological paper distribution, relevant papers, documents by subject area, and main countries. It is important to highlight that all papers found are case studies.

4.1 Publications Per Year

Figure 3 shows the chronological distribution of papers per year.

According to Fig. 3, the publications started in 2007. The pioneer author was (Burleson et al. 2007). After that, there was no publication on the proposed topics in the database Scopus, which does not mean that there were no publications in other databases. Also, it is noticed that from 2011 on, at least one paper was published on the topic here proposed, reaching out its peak in the year 2016, which shows a growing interest in that by authors.

4.2 Relevant Papers

Table 2 shows the five most cited ones—through Google Scholar.

According to Table 2, the paper with most citations (13) was "Sprock-it: A physically interactive play system" (Burleson et al. 2007), which besides being the most cited, it was the pioneer paper on Arduino and RFID. Its purpose is to present

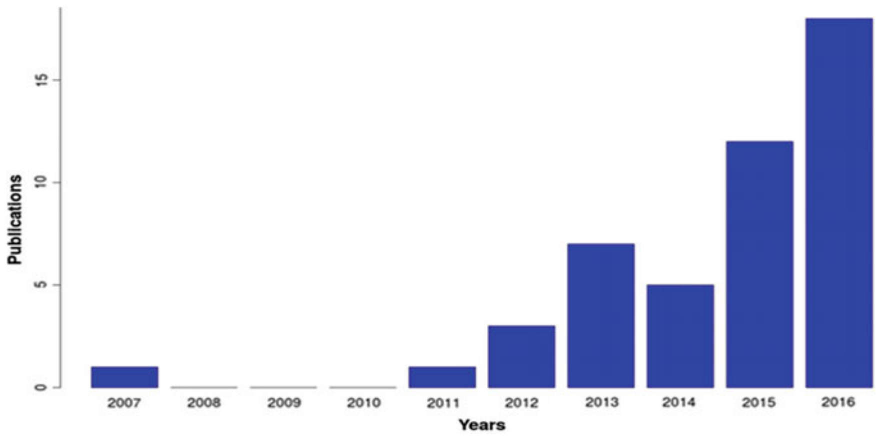

Fig. 3 Publications per year (The authors. 2017)

Table 2 The five most cited papers

Ranking	Authors	Title	Year	Citation count
1	Burleson W., Jensen C. N., Raaschou T., Frohold S.	Sprock-it: a physically interactive play system	2007	13
2	Elhart I., Memarovic N., Langheinrich M., Rubegni E.	Control and scheduling interface for public displays	2013	10
3	Eguchi A., Nguyen H., Thompson C. W.	Everything is alive: towards the future wisdom Web of things	2013	9
4	Manna S., Bhunia S. S., Mukherjee N.	Vehicular pollution monitoring using IoT	2014	5
5	Ang J. T., Chin S. W., Chin J. H., Choo Z. X., Chang Y. M.	ISCAPS—Innovative smart car park system integrated with NFC technology and e-Valet function	2013	5

Source (The authors)

the system development of Sprock-it, which is a hand-sized robotic character that encourages full-body interaction and engaging mental play. Other papers among the most cited are (Elhart et al. 2013; Eguchi et al. 2013; Manna et al. 2014) with 10, 9 and 5 citations, respectively.

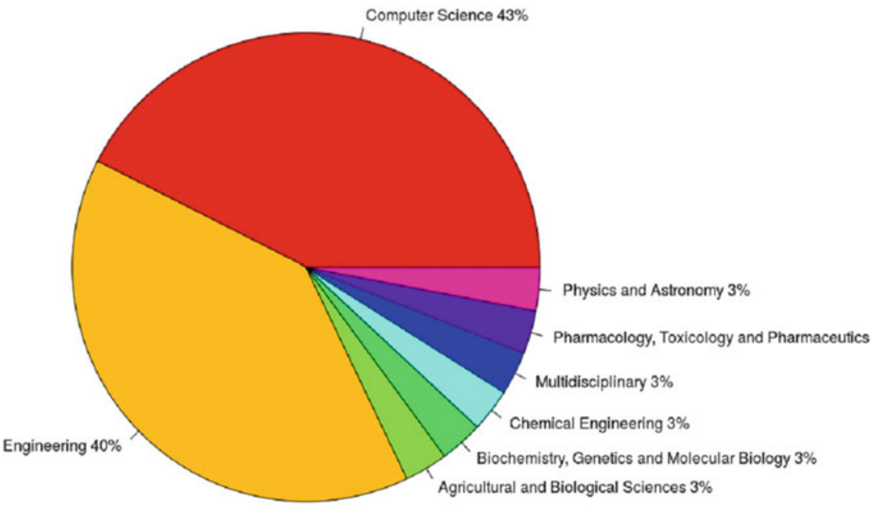

Fig. 4 Documents by subject area (The authors. 2017)

4.3 Documents by Subject Area

Figure 4 shows the percentage of documents by subject area. Obviously, the biggest numbers of papers were on Computer Science and Engineering, after all, this paper approaches two technological tools. However, through Fig. 4, we can also notice other areas such as Pharmaceutical, Agricultural, and Biochemistry with 3% for both of them. Also, it is worth highlighting that the results less than 1% were excluded from this visualization, but they simply can be obtained by following this paper methodology.

4.4 Main Countries

With the aid of the app VOSViewer, the analysis of the number of publications for countries showed that India had the largest one, followed by the USA, and Taiwan (Fig. 5).

The minimum was set at 1 document per country and included 17 countries. Countries with the highest number of publications have darker spot. In the map, India, the USA, Taiwan had the darkest spots, i.e. highest publications.

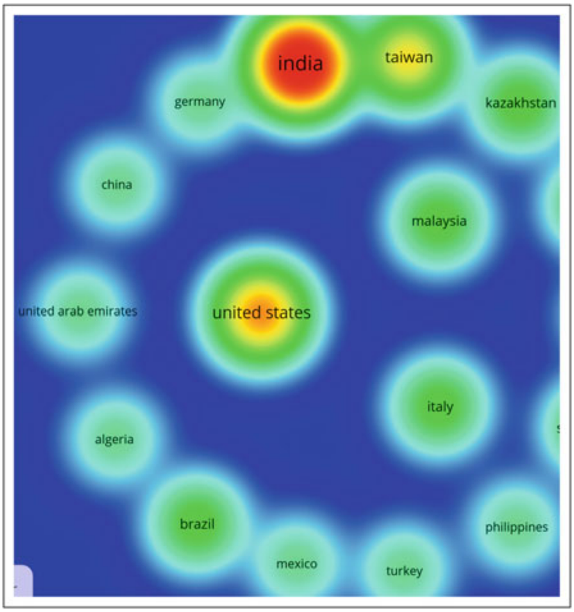

Fig. 5 Density visualization map for country publication (The authors. 2017)

5 Conclusions

This paper analyzed relevant papers on the proposed subject here. It was made through the citation count analyses, once when a paper is cited by others; it excels its importance for the literature. Besides that, it can be used as a bibliographic reference for future works, by leading other researchers to significant authors and papers. It can be done just by following this paper methodology.

It highlights how important computational tools are for generating bibliometric data. Otherwise, it would take a long time, due to the huge amount of data (47 papers). Moreover, these papers were classified as case studies developed in different countries, with the highest number of publications in India, the USA, and Taiwan.

As this paper is restricted only to one database, Scopus, there is a limitation on the retrieved data. Hence for future works, it is suggested to carry out a throughout content analysis for the most important papers found. Also, it is recommended to use other database—Web of Science, for instance—for data cross-checking, obtaining more accurate information to carry out further analyses on the use of Arduino and RFID and their implantation in Brazilian companies.

References

Aydos, T. F., & Ferreira, J. C. E. (2016). RFID-based system for Lean Manufacturing in the context of Internet of Things. In *IEEE International Conference on Automation Science and Engineering* (pp. 1140–1145). IEEE Computer Society. https://doi.org/10.1109/COASE.2016.7743533.

Burleson, W., Jensen, C. N., Raaschou, T., & Frohold, S. (2007). Sprock-it: a physically interactive play system. In *Proceedings of the 6th international conference on Interaction design and children* (pp. 125–128). ACM.

Eguchi, A., Nguyen, H., & Thompson, C. W. (2013). Everything is alive: Towards the future wisdom Web of things. *World Wide Web, 16*(4), 357–378. https://doi.org/10.1007/s11280-012-0182-4.

Elhart, I., Memarovic, N., Langheinrich, M., & Rubegni, E. (2013). Control and scheduling interface for public displays. In *UbiComp 2013 Adjunct—Adjunct Publication of the 2013 ACM Conference on Ubiquitous Computing* (pp. 51–54). https://doi.org/10.1145/2494091.2494106.

Fahimnia, B., Sarkis, J., & Davarzani, H. (2015). Green supply chain management: A review and bibliometric analysis. *International Journal of Production Economics, 162,* 101–114.

He, J., Atabekov, A., & Haddad, H. M. (2016). Internet-of-things based smart resource management system: A case study intelligent chair system. In *2016 25th International Conference on Computer Communications and Networks, ICCCN 2016*. Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/ICCCN.2016.7568533.

Huang, C.-H., Shen, P.-Y., & Huang, Y.-C. (2015). IoT-based physiological and environmental monitoring system in animal shelter. *Seventh International Conference on Ubiquitous and Future Networks, 2015,* 317–322.

Kamaraj, A., Radha, K., Priyanka, M., & Punitha, M. (2016). Intelligent transport system using integrated GPS optimized reader. In *2016 2nd International Conference on Science Technology Engineering and Management, ICONSTEM 2016* (pp. 332–336). Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/ICONSTEM.2016.7560972.

Manna, S., Bhunia, S. S., & Mukherjee, N. (2014). Vehicular pollution monitoring using IoT. In *International Conference on Recent Advances and Innovations in Engineering, ICRAIE 2014*. Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/ICRAIE.2014.6909157.

R Core Team. (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.r-project.org/.

Sharma, A., & Rani, R. (2015). IoT solutions for 3-D visualization of Twitter data. In *Souvenir of the 2015 IEEE International Advance Computing Conference, IACC 2015* (pp. 839–843). Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/IADCC.2015.7154824.

Tommy, R., Ravi, U., Mohan, D., Luke, J., Krishna, A. S., & Subramaniam, G. (2015). Internet of Things (IoT) expanding the horizons of Mainframes. In *2015 5th International Conference on It Convergence and Security (Icitcs)*.

Vaz, C. R., Inomata, D. O., Maldonato, M. U., Selig, P. M., & Varkasis, G. (2015). State of the art on intellectual capital research in Brazil: A structured literature review (2001–2014). *Business and Management Review, 4,* 463–472.

Vosviewer. (2017). Visualizing scientific lanscapes. https://www.vosviewer.

Identifying the Main Uncertainties in the Agri-Food Supply Chain

A. Ortiz, F. Alarcón, D. Pérez and M. M. E. Alemany

Abstract Change in products, process, technology and markets are significantly contributing to an increase in the uncertainty level of the Supply Chain. The result is that the companies must take decisions with less information or more ambiguous, on shorter times and with higher penalty costs. In the agri-food sector, managing the uncertainty is especially important, not only to control the effects of these factors, but also because it is a sector characterized by the existence of large sources of uncertainty throughout the process, from the growing in the countryside to the conservation in the retailers' shelves, with perishable products, special transport requirements or treatment of products that can suppose health risks. In this paper, a framework of analysis is presented to evaluate the impact of the sources of uncertainty on three key aspects (quantity, quality and time) for each of the stages of AF-SC and at each decision level (strategic, tactical and operational).

Keywords Uncertainty sources · Agri-food supply chain · Decisional levels

1 Introduction

Agri-food supply chains (AF-SCs) consists of organizations that are responsible for the production, distribution and sale of vegetable or animal-based products. In general, two main types of AF-SCs exist (van der Vorst 2000):

A. Ortiz · F. Alarcón (✉) · D. Pérez · M. M. E. Alemany
Research Centre on Production Management and Engineering (CIGIP),
Universitat Politècnica de València, Camino de Vera, s/n, 46022 Valencia, Spain
e-mail: faualva@cigip.upv.es

A. Ortiz
e-mail: aortiz@cigip.upv.es

D. Pérez
e-mail: dapepe@cigip.upv.es

M. M. E. Alemany
e-mail: mareva@cigip.upv.es

J. Mula et al. (eds.), *New Global Perspectives on Industrial Engineering and Management*, Lecture Notes in Management and Industrial Engineering,
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1. SCs for fresh agricultural products. Normally, these SCs are formed by growers, auctions, wholesalers, importers and exporters, retailers and speciality shops. The most important processes that these actors perform in the SC are the planting, harvesting, handling, storing, cleaning, sorting, packing, transportation, and especially trading of these goods. Examples of these SCs may be fresh vegetables, fruit or flowers.
2. SCs for processed food products. These SCs may comprise the same actors than the previous case, but with a special importance for the processors. They usually take the agricultural products as raw materials for producing products with higher added value. Some examples of these SCs may be desserts, snacks or canned food products.

Modern AF-SC involve millions of actors with different objectives and interests, organized in multiple stages, and continuously taking a great variety of decisions requiring complex, multilateral, and multilevel governance. For instance, there are several million farmers, several hundred thousand different food processors and retailers, and 500 million consumers in the EU. The figures are much larger if the total number of global agents who are involved in the EU AF-SC are taken into account (Bachev 2013).

This sector, complex in itself, is further complicated by the existence of high levels of uncertainty. According to van der Vorst (2000), SC uncertainty refers to “decision making situations in the SC in which the decision-maker lacks effective control actions or is unable to accurately predict the impact of possible control actions on system behavior”. It may occur because of a lack of information or understanding of the environment or also, because of a lack of a consistent model of the SC that include the relationships between SC variables and performance indicators.

van der Vorst (2000) affirms that one of the most important aspects in SCs is the uncertainty reduction in decision making. This uncertainty complicates or even may prevents that the logistical objectives of the SC can be reached, or that the customer orders can be achieved, for example, due to unexpected changes in the weather conditions that could have a huge impact on the quantity produce by the SC.

The management of high levels of uncertainty remains a major concern because of its high impact on the AF-SC decisions and its processes, despite the fact that, according to van der Vorst (2000), by breaking down the walls that are present between successive SC stages, decision making uncertainties may decline, since more information and control possibilities will become available to the decision-makers in each stage. In this line, Mor et al. (2015) conclude, from the comprehensive literature assessment, that the safety, quality and associated economic benefits in sustainable AF-SCs can be achieved through elimination of uncertainties, in addition to innovation, supply chain collaboration and introducing global supply chain practices into lean and green initiatives.

In this context, as a tool for the uncertainty analysis in the AF-SC, a framework of analysis is proposed to evaluate the impact of the sources of uncertainty on three key aspects (quantity, quality and time) for each of the stages of AF-SC and at each decision level (strategic, tactical and operational).

The remainder of this paper is organized as follows; in Sect. 2 the agri-food Supply Chain characteristics is described. Next, Sect. 3 addresses the decisions in the agri-food Supply Chain, establishing three decisional levels for each AF-SC stage. In Sect. 4 are listed the uncertainty sources and a possible classification of them. Section 5 contains a framework to quantify uncertainty sources impact in the agri-food Supply Chain and some quantification impact examples. The paper concludes by summarizing the main results.

2 The Agri-Food Supply Chain Characteristics

It is a widely accepted fact that the agri-food sector has a number of special features that make it especially complex. van der Vorst (2000) summarizes a list of specific process and product characteristics of AF-SCs from other papers and categorizes it by stage in the SC. Thus, in the Growers and Producers, it should be noted long production throughput times and seasonality in production, whereas in the Auctions/Wholesalers/Retailers we can find variability of quality and quantity of supply of farm-based inputs, seasonal supply of products requires global (year-round) sourcing, and requirements for transportation and storage means.

In general, according this author, the Food industry can be characterized by: (a) uncertainty about the quality and quantity of products supplied from farms, (b) production systems oriented to the volume instead the product variety, (c) systems focused on capacity utilization because of highly sophisticated capital-intensive machinery used, (d) high variability in the process yield, regarding quantity and quality obtained, due to biological variations, (e) high seasonality and existence of random factors as the pests, weather and other biological hazards that can act simultaneously, (f) alternative installations, cleaning and processing times highly product-dependent, (g) importance of the quality in all parts for that the agricultural inputs can be complementary, (h) importance of lot traceability of the product to control the work in process and to prevent quality problems, (i) necessity to storage the material, intermediates or finished products in containers or special tanks with special conditions, so can appear problems with the buffer capacity or bottlenecks, (j) importance of the recycling of materials and (k) decay for raw materials, intermediates and finished products that decrease the quality products along the process.

From a point of view of process, Verdouw et al. (2010) identify the basic trans-formations (or stages) in a generic fruit supply chain:

- **Growing and harvesting**: is the first stage and consist of the production of ripened fruit from inputs as seeds, trees, soil, water, fertilizers and pesticides. The basic activities are planting, pruning, thinning, fertilization, irrigation, crop protection and crop maintenance, and picking fruits from trees.

- **Washing, sorting and grading**: after harvesting, the fruits are usually washed in order to clean the earth and insects, and then sorted and graded according to its size, color, weight, ripeness or shape.
- **Processing**: consist in the transformation of fresh fruits into food products such as juices, jams, muesli or ice creams.
- **Packaging and labeling**: to facilitate its manipulation, storage and transportation, the fruit is packaged. It is very usual to add it also a label with product-related information that may be needed for further processing or for the customer, such as description, variety name, origin, harvesting date, product code, ingredients, etc.
- **Storage and distribution**: according to demand and taking into account the decay the fruit is receipted, warehoused, dispatched and transported to the wholesalers or to the retailers.
- **Retailing**: in the last stage, the fruit is delivered to the final consumers in specialized fruit and vegetables shops, supermarkets, markets in the street, restaurants, etc.

3 Decisions in the Agri-Food Supply Chain

Decision making in organizations usually follows a hierarchical approach. This mean that the decisions made at one certain level are constrained by those previously taken at the higher level, and besides, constraining those must be taken at the next lower level. Therefore, to understand and manage the organizational decision making processes, it will be very important understanding the interactions among managerial or hierarchical levels (Silver 1991). On the other hand, to take the best decisions, it will be necessary to consider several aspects such as profile of the decision maker, planning horizon, level of detail of the input information and uncertainty associated, and frequency of decision making. In accordance with Ganeshan et al. (1999) three levels of logistical management can be distinguished:

- **Strategic management**: At this level the organizational goals and the strategies for attaining these goals are defined. These decisions are mainly concerned with the establishment of the SC configuration.
- **Tactical planning**: At the second level the organizational goals and market performance demands are translated into logistical objectives. Tactical planning reflects decisions for the coming weeks or months. These decisions include the choices on and implementation of information systems and organization structures to be discussed in the next sections.
- **Operational control**: This managerial level is concerned with the daily operation of a facility to ensure that the most profitable way to fulfill actual order requirements is considered and executed. It contains all operational decisions, which directly influence the flow of materials or information. Typically, operational decisions reflect day-to-day operations up to two weeks in advance.

Taking this into account, it will be possible to structure the decisions in each AF-SC basic stage, discussed in previous section, according these three decision levels. In this way, we'll have a strategic level, a tactical level and an operational level for the growing stage, and the same for each stage in the AF-SC. In Table 1, it is shown the resulting matrix when crossing decision levels with AF-SC stages. Each quadrant has been denominated with a code formed by the first letter of the corresponding decision level (S-Strategic, T-Tactical, and O-Operational) and a correlative number for the SC stages (1–7).

In this way, some important decisions in each quadrant could be:

S1: Crops location, crops quantity.

T1: Month/week to plant seeds (the same decision for each sub-stage according previous section: growing includes activities such as planting, pruning, thinning, fertilization, irrigation, crop protection and crop maintenance).

O1: Week/Day to plant seeds (the same decision for each sub-stage according previous section: growing includes activities such as planting, pruning, thinning, fertilization, irrigation, crop protection and crop maintenance).

S2: Season in which you want to harvest.

T2: Month/week to harvest, quantity to harvest per week en each crop.

O2: Week/Day to harvest, quantity to harvest per day in each crop.

4 Uncertainty Sources and Classification

According to van der Vorst (2000), "*sources of SC uncertainty are inherent characteristics of the SC and characteristics of the managed system, managing system, information system and/or organization structure that are present at a certain point in time and that generate SC uncertainty*".

van der Vorst et al. (1998) identify four main uncertainty sources (US): (a) the first and main cluster of sources of uncertainty is the total order forecast horizon, (b) the second cluster of sources of uncertainty is related to input data available for a decision, (c) the third cluster refers to administrative and decision processes, and (d) the last cluster of sources of uncertainty in (especially food) supply chains is inherent uncertainty in demand, process and supply.

Table 1 Decisions levels for each AF-SC stage

	Fruit producer			Trader		Retailer	
	Growing	Harvesting	Distribution	Washing, sorting, packaging	Labelling, distribution	Receive, replenish	Check out at point of sale
Strategic	S1	S2	S3	S4	S5	S6	S7
Tactical	T1	T2	T3	T4	T5	T6	T7
Operational	O1	O2	O3	O4	O5	O6	O7

Other US's are: weather, plagues, natural disasters (fire, flood,…), diseases (plants and livestock), seeds quality, effects of fertilizers, ripening pace, agricultural machinery breakdowns, waste rate, product quality decay influences shelf life, product loss at transport/distribution stage because of accidents, delivery time overdue because of traffic congestion or vehicle breakdown, machine breakdowns, scrap rate, strikes, illness of staff, changes in laws and regulations, changes in trade agreements between countries or regions, new descriptions or technological/biological advances, customer demand and competitors influence.

On the other hand, van Donselaar (1989) identifies four ***types*** of uncertainty in the SC:

1. **Demand** uncertainty, associated to the customer's orders.
2. **Supply** uncertainty, taking into account the delivery of raw materials in time, according to the customer specifications and in the right amount.
3. **Process** uncertainty, inherent to the production system and related to the machinery breakdowns or the manufacturing and setup times.
4. **Planning and control** uncertainty, related, for example, to the difficulties to know accurately inventory levels, with to make a right forecasting, with the fulfilling delivery times or with the correct communication about the customer requirements.

These types of uncertainty sources allow us reordering the above uncertainty sources in the following way (Tables 2 and 3).

Table 2 Uncertainty sources classified by type

Supply	Process	Demand	Planning and Control
Weather, plagues, natural disasters (fire, flood,…), diseases (plants and livestock), seeds quality, effects of fertilizers, ripening pace, agricultural machinery breakdowns, inherent uncertainty	Machine breakdowns, scrap rate, inherent uncertainty	Changes in trade agreements between countries or regions, customer demand, competitors influence, inherent uncertainty	Input data available for a decision
Administrative and decision processes			
Waste rate, strikes, illness of staff, product quality decay influences shelf life, product loss at transport/distribution stage because of accidents, delivery time overdue because of traffic congestion or vehicle breakdown, changes in laws and regulations, new descriptions or technological/biological advances			

Table 3 Connection between Decisions levels for each AF-SC stage table (Table 1) and uncertainty sources classified by type table (Table 2)

	Fruit producer			Trader		Retailer		Customer
	Growing	Harvesting	Distribution	Washing, sorting, packaging	Labelling, distribution	Receive, replenish	Check out at Point of Sale	Buy
Strategic	S1	S2	S3	S4	S5	S6	S7	
Tactical	T1	T2	T3	T4	T5	T6	T7	
Operational	O1	O2	O3	O4	O5	O6	O7	

Supply	Process		Demand
weather, plagues, natural disasters (fire, flood,...), diseases (plants and livestock), seeds quality, effects of fertilizers, ripening pace, agricultural machinery breakdowns, inherent uncertainty	machine breakdowns, scrap rate, inherent uncertainty		changes in trade agreements between countries or regions, customer demand, competitors influence, inherent uncertainty
waste rate, strikes, illness of staff, product quality decay influences shelf life, product loss at transport/distribution stage because of accidents, delivery time overdue because of traffic congestion or vehicle breakdown, changes in laws and regulations, new descriptions or technological/biological advances			
administrative and decision processes			
Planning and Control			
input data available for a decision			

This US classification can be easily connected with the above table (Table 1) about decision levels and AF-SC stages due to Supply, Process and Demand are conceptually like successive stages in a SC. In this way, it can be drawn the following relations.

5 Quantifying Uncertainty Sources Impact in the Agri-Food Supply Chain

Regardless of whether an US may be more or less important at any given time, or at any stage, there are three aspects in the SC that can be affected: quantity, quality or time aspects (van der Vorst 2000). Hence, each US could be analyzed according the amount of impact (high ↑, low ↓ or none “ ”) it exerts on each aspect (quantity = QN, quality = QL and time) of each AF-SC stage and in each decisional level, as shown in the table, for the fruit producer stage at operational level:

	Fruit producer								
	Growing			Harvesting			Distribution		
Strategic	S1			S2			S3		
Tactical	T1			T2			T3		
Operational	O1			O2			O3		
	Supply								
Weather	QN	QL	TIME	QN	QL	TIME	QN	QL	TIME
	↑	↑	↑	↑	↑	↑			↑
Plagues	QN	QL	TIME	QN	QL	TIME	QN	QL	TIME
	↑	↑		↑	↑				
Natural disasters	QN	QL	TIME	QN	QL	TIME	QN	QL	TIME
	↑	↓		↑	↓				↑
Diseases	QN	QL	TIME	QN	QL	TIME	QN	QL	TIME
	↑	↑	↓	↑	↑	↓			↓
Seeds quality	QN	QL	TIME	QN	QL	TIME	QN	QL	TIME
	↓	↑	↓	↓	↑	↓			↓
Effects of fertilizers	QN	QL	TIME	QN	QL	TIME	QN	QL	TIME
	↑	↑	↑	↑	↑	↑			↓
Ripening pace	QN	QL	TIME	QN	QL	TIME	QN	QL	TIME
			↑		↓	↑			↓
Agric.machin. breakdown	QN	QL	TIME	QN	QL	TIME	QN	QL	TIME
						↑			↓
Inherent uncertainty	QN	QL	TIME	QN	QL	TIME	QN	QL	TIME
	↑	↑	↑	↑	↑	↑			↓

So, we could say, for example, that the seeds quality can have a low impact in the amount of product (quantity) that will grow and will be harvested, a high impact in the quality of product that will grow and will be harvested, and a low impact in the time of grow and will be harvested. On the other hand, the seeds quality won't have any impact in the quantity or quality of distribution, while it could have a low impact in the time the distribution takes place.

6 Conclusions

In this paper, we have enumerated several US's in the AF-SC and we have presented a framework to evaluate the impact of the US's on three key aspects (quantity, quality and time) for each of the stages of AF-SC and at each decision level (strategic, tactical and operational). The impact evaluation of the US allows to better know the importance of each US and, hence, to define specifics actions trying to reduce this uncertainty.

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References

Bachev, H. (2013). Risk management in the agri-food sector. *Contemporary Economics, 7*(1), 45–62. https://doi.org/10.5709/ce.1897-9254.73.

Ganeshan, R., Jack, E., Magazine, M. J., & Stephens, P. (1999). A taxonomic review of supply chain management research. In S. Tayur, R. Ganeshan, & M. J. Magazine (Eds.), *Quantitative models for supply chain management* (pp. 839–879).

Mor, R. S., Singh, S., Bhardwaj, A., & Singh, L. (2015). Technological implications of supply chain practices in agri-food sector—A review. *International Journal of Supply and Operations Management, 2*(2), 720–747.

Silver, E. A. (1991). Modelling in support of continuous improvements towards achieving world class operations. In R. K. Sarin (Ed.), *Perspectives in operations management*. Kluwer.

Verdouw, C. N., Beulens, A. J. M., Trienekens, J. H., & Wolfert, J. (2010). Process modelling in demand-driven supply chains: A reference model for the fruit industry. *Computers and Electronics in Agriculture, 73*(2), 174–187. https://doi.org/10.1016/j.compag.2010.05.005.

van Donselaar, K. (1989). *Material coordination under uncertainty: Towards more flexible planning concepts*.

van der Vorst, J. G. A. J. (2000). *Effective food supply chains generating, modelling and evaluating supply chain scenarios*. Wageningen University. ISBN 90-5808-261-X.

van der Vorst, J. G. A. J., Beulens, A. J. M., de Wit, W., & van Beek, P. (1998). Supply chain management in food chains: improving performance by reducing uncertainty. *International Transactions in Operational Research, 5*(6), 487–499. https://doi.org/10.1111/j.1475-3995.1998.tb00131.x.

Wilding, R. (1998). The supply chain complexity triangle: Uncertainty generation in the supply chain. *International Journal of Physical Distribution & Logistics Management, 28*(8), 599–616. https://doi.org/10.1108/09600039810247524.

Environmental and Financial Improvements Due to the Use of Ecodesign—In One Furniture Industry

E. M. Costa, M. O. Pedrosa, M. Vieira and E. A. Baptista

Abstract In the quest for greater competitiveness or profit, organizations often resort to using structured methods to achieve reductions in their costs and expenses. In this way, the objective of this article is to show that, concurrently with efforts to reduce operating costs, it is plausible to achieve, even if involuntarily, significant environmental improvements. This verification could be carried out through a case study in a furniture industry of the Brazilian furniture sector in which the ecodesign was adopted to obtain reduction of the operational costs. Once the implementation of ecodesign in a product line was completed, even without considering the environmental aspects, it could be verified that they also presented significant gains to the improvement of the environment.

Keywords Ecodesign · Environmental performance · Ecoefficiency
Furniture industry

1 Introduction

Nowadays, with the evolution of globalization, companies are looking for innovative solutions to become more competitive, so some of these solutions turn out to be trends, sometimes to comply with legislation or to be the theme of the moment (IEMI 2016). In fact, in the present, there is a theme that can no longer be left aside by organizations or even academy—sustainability, which encompasses three pillars of performance: the ecological/environmental, the economic, and the social (Despeisse et al. 2012; Santos 2013). Even with the increase of the studies and researches of the subject, it is restricted to the large organizations, although there are few applications to the small companies most of the time in a sectoral and

E. M. Costa · M. O. Pedrosa · M. Vieira · E. A. Baptista (✉)
Programa de Pós Graduação Em Engenharia de Produção, Universidade Nove de Julho,
Av. Francisco Matarazzo, 612 - 1º Prédio C, São Paulo 05001-100, Brazil
e-mail: elesandro@elesandro.eng.br

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localized way, assuming the character of a pilot work only for sensitization and awareness of the entrepreneur (Verfaille and Bidwell 2000; ABNT 2015).

An example of such initiatives is the ecodesign project implemented in 600 companies in the Netherlands by a network of 20 regional centers spread with the aim of increasing the innovation capacity of Dutch industry, especially with regard to SMEs. It was adopted as a specific approach to explore the commercial and cost reduction potential of ecodesign (Van Hemel and Cramer 2002). Network members pool efforts, exchange experiences and often develop systems together to strengthen sustainability practices and encourage companies to become more competitive, innovative and environmentally responsible.

However, it is observed that when such work is carried out, factors related to the positive or negative impacts on the environment are rarely considered. Thus, the main objective of this article is to show that, in parallel with efforts to reduce operating costs, it is possible to obtain significant environmental gains that can be measured by the evolution of the company's eco-efficiency level, even if unintentionally. In this article, this was done through a single case study in which the concept of ecodesign was applied on the manufacturing process of a furniture company that uses medium and high density fiberboard (MDF—Medium Density Fiberboard/MDP—Medium Density Particleboard/HDF—High Density Fiberboard) of the Brazilian furniture industry. The goal originally sought by the managers of this company was to improve the design of the product and or minimize the costs related to the inputs and resources used in the process. After the implementation of the improvements in the production process, it was verified that they also brought significant contributions to the protection of the environment, which were evaluated through the measurement of the level of ecoefficiency of this process before and after the implementation of the changes made.

2 Methodology

The appropriate method to meet the objective of this article was the case study because this research considered here focused on "how/why" questions and also evaluated a current phenomenon in the real context and in which the boundaries between the two were not clear (Yin 2009). In order to choose the company evaluated, it is recommended to select samples with content from which it is possible to obtain significant information about the subject matter at the heart of the research (Patton 1990). Which in the case study considered is ecodesign. Based on this approach, two criteria were established for the choice of the company that would compose the case study: (a) it should have recently implemented ecodesign projects to reduce operating costs; (b) it should allow researchers access to all the data and information necessary to carry out the present research, including real financial gains. Complying with these criteria, a medium-sized firm was selected from the furniture sector located in the furniture pole of Arapongas in the State of Paraná. It is a medium-sized family company with national capital that is dedicated to the manufacture of products for kitchens, living rooms, living room and dining room. It has about 150 employees and has an average annual turnover of R$ 40,000,000.00.

As a procedure for data collection in the selected company, it was decided to use the semi-structured interview because it is considered the best option when planning to conduct research based on case studies (Bryman 1995; Collins and Hussey 2003).

In this line, González-García et al. (2014) mention a set of seven steps for development and an ecodesign project in Small and Medium-sized Enterprise (SME). (A) Phase knowledge of the structure of the company and its operating scheme: in this first phase, due to the objective to be achieved, it is necessary to develop a map of the SME itself and of all contracted suppliers. (B) Phase of selection of the multidisciplinary work team: it defines the agents and the parties involved in the tasks. (C) Phase identification of the product to be eco-redesigned and its value: Here the product to be applied ecodesign should be defined. (D) Environmental Inventory Phase: This phase comprises the inventory of input/output data (material and energy flows and environmental emissions) for a given product. (E) Phase of application and results of the Assessment of the Life Cycle: In this phase one must apply the quantitative environmental tools offer reliable results. (F) Ecobriefing phase, including adaptation of the lean management system: This phase will be carried out based on the previous phases and on the interpretation of the results obtained in Phase V. (G) Proposed phase and choice of environmental improvement actions: The purpose This phase is to make a series of proposals (e.g. in the areas of design, material selection, transport, etc.) to improve the environmental impact of the product and meet ecobrief requirements.

That is, from the receipt of raw material until the shipment of the finished products and the consumption of water employed throughout the process. Thus, three eco-efficiency indicators, following the principles defined by Verfaille and Bidwell (2000) (value of the product or service/its environmental influence) were adopted for the present study as shown in Table 1.

It should be noted that following the recommendations of Lucato et al. (2013) (e_1, e_2 and e_3) must have the same orders of magnitude, which is why the units of

Table 1 The performance indicators for the eco-efficiency measure in the case studied

Indicator	Product or service value	Environmental influence	How to measure
e_1	RLM Monthly net turnover (R$)	MEEC Monthly energy consumption (KWh)	MNT/MEEC (R$/KWh)
e_2	RLM Monthly net turnover (R$)	SW Solid waste (100 kg)	MNT/SW (R$/100 kg)
e_3	RLM Monthly net turnover (R$)	MWC Monthly water consumption (10 cm^3)	MNT/MWC (R$/10 cm^3)

measurement shown in Table 3 were those adopted in this study. Once the environmental performance indicators to be used were defined, the next step was to introduce the data in relation (1) to the calculation of the level of eco-efficiency in the furniture process of the company studied:

$$\begin{aligned} E_{\mathrm{Pt}} &= [e_1 \times e_2 + e_2 \times e_3 + e_1 \times e_3] \times \frac{\mathrm{sen}120}{2 \times 3} \\ &= 0.1447 \times [e_1 \times e_2 + e_2 \times e_3 + e_1 \times e_3] \end{aligned} \tag{1}$$

Based on this construction it was possible to measure the level of eco-efficiency of the studied process and thus relate the impact of its actions and its economic and environmental performance.

3 Case Study: Economic Gains Obtained Through Eco-design

First, the phases of the ecodesign methodology for reducing operating costs and measuring the level of eco-efficiency were considered.

Phase 1: knowledge of the company structure and its operating scheme: The steps taken by the company to implement the ecodesign followed step-by-step. As a first step in the process, the survey of all suppliers of the inputs used. As well as the prices practiced and the use of each raw material in the manufacturing process, the same was done for the suppliers of the distribution and commercialization.
Phase 2: selection of the multidisciplinary team: In the second phase of implementation, a multifunctional team was defined and composed of a marketing manager, an industrial director, a production engineer, a designer, and a specialized chemist in the environment. In this way, it was possible to structure a working group with the minimum of knowledge and professional experience for the success of the project.
Phase 3: identification of the product to be eco-redesigned and its value: At this stage the value of the first product worked by the company was identified as a popular kitchen that presented in the study of value to the customer the following: the kitchen is designed as equipment for installations and offices, the main customers of the company are large networks of magazines that resell the product to the final consumer class C, D and sometimes B.
The value recognized by customers that was identified in the study were, in order of preference: design Product level, functionality level, product versatility, finish, ease of assembly and durability.
Phase 4: doing the Environmental Inventory: already this phase spends the company the greatest effort is here the implementation of the ecodesign needs to have in hand all the inventory data to build the study and analysis of the product life cycle. And to get high-quality data and information it is essential to make a reliable

assessment. In this study, the limits of the system considered were from the receipt of the raw material to the dispatch of the finished product. As it was identified that purchases are made through a small range of suppliers having a maximum of two suppliers for each input facilitated and made the compilation of the information a less complex task. But with the low bargaining power with suppliers, the accuracy of some data information was reduced. Given the lack of objective and direct data, in drawing up the inventory based on the data provided by the suppliers. The main residues detected in the outflow: excessive residues of raw materials (e.g. in the case of packaging, particle board from the cutting plane and poor utilization of the sheet, i.e. 50–70% of the raw material used).

Phase 5: Application and Results of the Life Cycle Assessment: The company chose not to hire a specialist to present the information and results of the LCA case study. Due to the lack of availability of qualified professionals in the region and the high costs of hiring this professional from another city. This activity is critical to obtaining the phase 1 map prior to the application of the ACL, as well as the environmental inventory. With the decision not to hire a specialist this phase of environmental impact measurement was compromised, leaving only the evaluation of the level of eco-efficiency as already presented in this article.

Phase 6: elaboration of ecobriefing, including the adaptation of the lean management system: Here we identified two main characteristics to be considered for the implementation of ecodesign the first is that the need for review and resizing of product inputs and another point Important is the internal logistics review of products.

Phase 7: proposal and choice of environmental improvement actions: Based on the goals of reducing costs and improving the design of the company's products, the surveys carried out in the previous phases were used and the need to carry out the following improvement actions was identified: Dematerialization reduction of the thickness of the particleboard and MDF used; Revision of the product design observing the best use of the cutting plan, modularization and standardization of parts and drillings; Developing two-sided products to increase product flexibility for the end customer; Changing the finished stock strategy by transferring the stock of finished product to a stock before painting.

Implementation of systematic and continuous control of wastes in the manufacturing process; Also in this phase all the technical data sheets and the process scripts of the selected products were revised in order to validate their respective costs; The result of this process of implementation of ecodesign has been to achieve significant cost reduction as well as greater identification with the final consumer by increasing sales volume. Table 2 shows the gains achieved considering the annual result for 2015 (before applying the ecodesign) and the accumulated result in 2016 (after the application of the actions proposed by ecodesign and due time for the stabilization of the processes). It should be noted that the volumes of products produced and marketed in these two periods were significantly different, since average monthly net sales grew by more than 25.7% as shown in Table 2 (from R$ 33,431,774 thousand in 2015 to R$ 42,037,819 thousand in 2016). To consider the effect of this growth on the economies generated, it was calculated what would be

Table 2 Annual results obtained from the application of the ecodesign in the selected company

(Values expressed in R$)	No *Ecodesign* (2015)	No *Ecodesign* (2016)	With *Ecodesign* (2016)	Red R$	Red %
Monthly net turnover	33,431,774	42,037,819	42,037,819		
Consumption of raw material	16,154,584 48.32%	20,312,674 48.32%	17,939,746 42.67%	2,372,928	11.68%
Cost of electric power	1,481,215 4.4%	1,862,511 4.4%	1,552,695 3.7%	309,816	16.63%
Solid waste	646,183 1.93%	812,524 1.93%	448,493 3.5%	364,031	44.80%
Water consumption	66,240 0.20%	83,292 0.20%	63,664 0.15%	19,628	23.56%
Total	18,348,222 54.9%	18,348,222 54.9%	20,004,598 47.6%	3,066,403	13.29%

Table 3 Annual results of the selected eco-efficiency indicators

		No *ecodesign* (2015)	With *ecodesign* (2016)	Var %
Monthly net turnover (R$)		33,431,774	42,037,819	25.7
Cost of electric power	KWh e_1 (R$/KWh)	3,193,968 10.47	2,678,481 15.69	49.9
Solid waste	100 kg e_2 (R$/100 kg)	11,580.35 28,87	6,4300.2 52.30	81.1
Water consumption	l e_3 (R$/l)	720,000 46.43	692,000 60.75	30.8
Ecoefficiency level	E_M	308.02	716.48	132.6

the consumption of each item in the second year 2016 if the actions resulting from the ecodesign had not been adopted. It was in relation to this new number that the reductions obtained were calculated.

It can be observed that the raw material savings were quite representative. There was a reduction of 11.68% in the cost of the raw materials used, 16.63% in the cost of electricity, 44.80% in the cost of inputs transformed into solid waste, 23.56% in the cost of water, Representing a reduction in the company's operating cost of almost 13.29%.

Observing the information in this Table 3, it is possible to notice that the levels of ecoefficiency presented an increase of 49.9% for the consumption of electric power, 81.1% of environmental gain for the reduction of solid waste generation and an increase of 30.8% in eco-efficiency for water consumption.

Also, the application of the above mentioned Table 3 relationship allowed to identify that the ecoefficiency level of the furniture manufacturing process, considered as a whole, increased from 308.02 in 2015 to 716.48 in 2016, showing an environmental gain of the order of 132.6%.

It should be noted that, even without taking into account environmental concerns, the actions taken by adopting a structured ecodesign approach to reduce operating costs have a very favorable impact on the environment. Moreover, one can even argue that the latter were more relevant because, while monetary gains reached a 13.29% reduction in operating costs, the environmental gains measured by the evolution of the eco-efficiency level showed an evolution of 132.6%, which responds in an affirmative way to the research question proposed by the present

4 Conclusion

Recently, even with the subject of sustainability in the media and with different areas of knowledge investigating and exploring the subject, it is still not common to apply these concepts to small and medium-sized enterprises, in which concerns about survival in the short Define all strategic and operational priorities. The case studied in this article proved this idea by showing the application of a structured tool to reduce costs and environmental gains, in which the company that applied it and did not take into account the possible environmental impacts. However, through the measurement of the eco-efficiency level of the analyzed area, before and after the cost reduction actions, the authors of this work were able to show that, even involuntarily, the actions taken to reduce the operational costs were reflected in a relevant way on the Level of ecoefficiency, characterizing an important contribution to the environment and providing a positive answer to the central question proposed by this study. However, it is relevant to point out that even the company did not strictly comply with all the steps of the instrument chosen by the company, it was possible to obtain significant results.

In this way, this work contributes to the expansion of knowledge in the field of Production and Operations Engineering, insofar as it collaborates with the literature when verifying that processes by adopting a method that associates environmental gains and reduction of operational costs can bring improvements To the environment, even if such progress occurs even involuntarily. At the same time, the content presented here brings to the managers of the companies the concept that the environmental impacts of their activities can be reduced without costs or additional investments. On the other hand, as evidenced by the present development, environmental improvement can be characterized by the simple measurement of its indicators, since the actions usually taken to reduce costs can bring with it an increase in the level of eco-efficiency of the considered process and of the company as one all.

Of course, this work has certain limitations. One of the first is because it is a single case study, in this way the conclusions cannot be used in a generalized way. At the same time it is important to take into account that the present study analyzed only one particular industrial process in the context of the furniture industry. There is a good chance of getting different results if applied in different situations. Therefore, in order to expand the findings of the present study, future research should consider a larger number of companies, involving different production processes, belonging to different industrial segments.

References

ABNT—ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR ISO 14031. (2015). Gestão Ambiental – Avaliação de Desempenho Ambiental – diretrizes. Rio de Janeiro.

Bryman, A. (1995). *Research methods and organization studies*. London: Routledge.

Collins, J., & Hussey, R. (2003). *Business research methods*. New York, NY: McGraw-Hill.

Despeisse, M., Mbaye, F., Ball, P. D., & Levers, A. (2012). The emergence of sustainable manufacturing practices. *Production Planning & Control, 23,* 354–376.

González-García, S., Salinas-Mañas, L., García-Lozano, R., Gabarrell, X., Rieradevall, J., Feijoo, G., & Moreira, M.-T. (2014). Application of ecodesign methodology in SMEs run according to lean management: the case of a furniture publishing Company. *Environmental Engineering and Management Journal, 13*, 2977–2988.

IEMI. (2016). Relatório setorial da indústria de móveis no Brasil. São Paulo: IEMI – Instituto e Estudos de Marketing Industrial, Brasil Móveis.

Lucato, W. C., Vanalle, R. M., & Santos, J. C. S. (2013). Uma avaliação das práticas e do desempenho ambiental do setor industrial na regial metropolitana de São Paulo. *Espacios (Caracas), 34,* 3–13.

Patton, M. Q. (1990). *Qualitative evaluation and research methods*. Newbury Park, CA: Sage.

Santos, J.C.S. (2013). Integração da Técnica Seis Sigma (DMAIC) com Métricas Ambientais para a Busca de Melhorias na Ecoeficiencia de um Processo Industrial. f. 95. Dissertação (Mestrado em Engenharia de Produção) Universidade Nove de Julho – UNINOVE, São Paulo.

Van Hemel, C., & Cramer, J. (2002) Barriers and stimuli for ecodesign in SMEs. *Journal of Cleaner Production, 10*, 439–453.

Verfaille, H. A., & Bidwell, R. (2000). Measuring ecoefficiency—A guide to reporting company performance. Geneva: WBCSD—World Business Council for Sustainable Development.

Yin, R. K. (2009). *Case study research: Design and methods* (4th ed.). Newbury Park, CA: Sage.

Part IV
Quality and Product Management

Competitive Priorities in the Hotel Sector of Sinop—Located in Northern *Mato Grosso*–Brazil

H. C. Lopes, J. M. S. Galante, C. P. Leitner, A. M. Sznitowski and S. Baggenstoss

Abstract The production strategy leads the companies to stand out through their competitive priorities, which presents the relevant element in the strategy of development. Therefore, the present study has as objective to analyse which the competitive priorities the hotel sector has used to get strategic advantage in the market. The research was conducted in Sinop, city in the north of the Mato Grosso state–Brazil. The methodology is characterized as exploratory research, using the theoretical and methodological assumptions of qualitative approach for comprehension of the studied phenomenon. In conducting of the research were listed five hotels of the city, in which were applied questionnaires to fulfil the objectives. To the analysis were chose the following priorities: velocity, reliability, cost, quality and flexibility, according to Slack et al. (Administração da Produção. Atlas, São Paulo, 2009). With that, it was possible to identify that the quality is the competitive priority that is most present in the researched companies. It was also found that the greater hotel demand is from business tourists.

Keywords Hotel business · Production strategy · Competitive priorities

H. C. Lopes · J. M. S. Galante · S. Baggenstoss (✉)
Departamento de Administração, Universidade Do Estado de
Mato Grosso, Av. Ingas, 3300, Sinop, Mato Grosso 78550-000, Brazil
e-mail: salli@unemat-net.br

H. C. Lopes
e-mail: heloisa_lead@hotmail.com

J. M. S. Galante
e-mail: juli-m@bol.com.br

C. P. Leitner · A. M. Sznitowski
Departamento de Administração, Universidade Do Estado de
Mato Grosso, Rodovia MT-358, Km 07, Tangará Da Serra,
Mato Grosso 78300-000, Brazil
e-mail: camyla.piran@gmail.com

A. M. Sznitowski
e-mail: adeliceadm@gmail.com

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1 Introduction

One of the firsts items to be analysed when planning a trip, independent of the purpose, is where will stay during that determined period. The lived experience and the way as the client is treated during the period of stay influence the return and the impression he will have of the place visited.

In the last years the hospitality sector has grown significantly, not only in Brazil, but in the whole world. It is part of the service sector, which is the relevant part of Gross Domestic Product (GDC), according to the Brazilian Institute of Geography and Statistics (IBGE).

According Cobra (2001), the tourism is the economic activity that should grow up in the XXI century. In the most closely countries linked to the branch, is the services economy sector that leads the labour market. Being that the tourism enterprises don't make distinction between rich country, poor, large, medium or small.

The Mato Grosso state has been conquering forces in this branch due to the incentive of the public managers and the private initiative which commit to highlight the State as in the country as in the world. Besides that, the Government of the State has interest in make this sector one of the economic pillars in the state (SEDtur 2010).

It is known that the majority of the hotels in our country is classified as micro and small business, according the Ministry of Tourism (2006), and that they tend to have a difficulty in the elaboration of a strategic planning, according Bortoli Neto (1994). In addition, in the face of the expected growth, there is necessity for these companies to prepare good strategies that, besides satisfying the desire of his clients, make them stand out in the market.

Understanding that according the elaborated planning, the company services department will must be adjusted to perform what was determined and with that to reach the objectives. According Porter (1989), the competitive priority is a tool that leads the strategy of operation, making a company stands out from the others, with the condition that the competitive priority is clearly present in the strategy of the company. By this mean, so the company becomes known for its competitive priority.

And is in this context that the study was elaborated, with the objective of understand which behaviour of the hotel sector in this region of Brazilian Amazon and, through identifying the most commonly used competitive priorities, to understand how the hotels has been lead its operations and positioning itself in the market (De Siqueira 2009; Porter 1989). Sinop is a new city with about 120 thousand residents, known as a pole in the services, agribusiness and education sectors. According city hall information, in 2015, the Sinop hotel sector had twenty-six hotels, which added a total of 862 bedsteads (bedrooms).

2 Competitive Priorities

Porter (1989) claims that because of the intensification of competitiveness generated by globalization, the companies started to adopt a strategy that enables them to get advantage in the segment that the belong. For that, the companies elect a competitive priority so that they can succeed and remain in the market.

The major purpose of the competitive priority is the competition and sustenance of growth, which is made for long term, because a company just is known by its competitive priority when it stops being just a competitive factor and become a strategy. This to it obtains something different from the other companies. However, it is important to remember that the priorities are directly related to the capacity it has to offer that determined product or service (Porter 1989).

The stakeholders (suppliers, customers and competitors), all those who are involved in activities of operations, are the responsible in determining the competitive strategy. The customers mainly because are the main consumers of product or service (Slack et al. 2009).

De Siqueira (2009) says that competitive priorities are strategies that have been identified as common among the companies. These strategies increase the power of competitiveness and usually are always related with the extern factors. Production has the main function understand and identify these competitive priorities and establish its strategies. Due to the fact that each company has its own characteristics and routines, they determine its strategy according to the objectives defined by the same. There are several authors that define these priorities in many ways, but the most commons are quality, cost, flexibility, velocity and reliability.

According Nogueira et al. (2001), such priorities must guide all decisions, the programs and the actions implemented in the areas of structural decision (location and capacity, installations and equipment, product and process technology and vertical integration) and infrastructures (organization, human resource management, logistic and planning and control of production and quality management).

Barros Neto et al. (2003) claim that the strategy of production start with the definition of competitive strategy and then starts with the choice of the competitive criterion, which must be the priority of production.

Is interesting to highlight what Filho et al. (1995, p. 3) claimed about the competitive priorities. To the authors, must not be confused with generic competitive strategies of Porter (1989), because these reach the alternatives of competition in a business unity in the choice market segment. Therefore, condition the definition of all functional strategies, including the Strategy of Production.

For this job, were considered the competitive priorities presented by Slack et al. (2009). Are them: quality, velocity, reliability, flexibility and cost, exposed in the sequence.

2.1 Quality

The quality must be coherent consistent with customer expectations. It is about to perform correctly the production of product or service. Is necessary to exist a minimum required, that be this supply to necessities of customer. This is an important priority, because us a fundamental factor to the customer buys again a product or uses a service and makes the intern costumers feel satisfied (Slack et al. 2009).

To Jacobs and Chase (2012), quality is directly connected to the process and the planning, that is, connected to the structure of product. Knowing that the more elaborate the product the greater the price. However, is fundamental the production without defects, independent of product complexity.

2.2 Velocity

Velocity is a priority that concerns to the time that the organizations take to correspond their client and delivers their product or service. Is important to point, that to get the product deliver quickly, It is not just the operations department that needs to be agile, but the others departments too.

This priority also helps in the stock reduction, because when faster is the production, the product will be delivered faster to the client, so the stock will be reduced. If you have less stock, you have less cost (Slack et al. 2009). In the services area, that priority is quite considerable, since often when a client goes looking for a service because he needs immediately. An example could be the medical services. (Filho et al. 1995)

2.3 Reliability

The reliability runs when the product delivered in the determined time (combined) or when a service is delivered when it is exactly necessary. It becomes crucial to the client keep opting for that determined product. Slack et al. (2009) claim that at the outset it is not the most important priority, but in course of time it can turns the most important of all (Slack et al. 2009). Reliability is also necessary in the internal operations. For example, in a car assembly line, how the pieces are made separately, and after go to the assembly, if the pieces will not delivered in the correct time, the client will have the product late. It reduces the reliability, as of the internal operation as of the final client (Slack et al. 2009).

2.4 Flexibility

The flexibility is the capacity of change of any stage of operation. Filho et al. (1995) indicate that flexibility is about a skill to respond effectively the circumstantial changes. To Slack et al. (2009) there are many kinds of flexibilities: of product, compost, volume and deliver. The flexibility of products/services is defined as a capacity to change, introduce something different in the product. The flexibility of compost determined by the mix of products that are offered. The flexibility of volume is the capacity to change the quantity of product/service. Moreover, flexibility of delivery expresses the possibility to change the delivery of product/service. One of the advantages of express delivery is the opportunity to attend several types of clients, that is, attend the biggest slice of the market. It gives agility of the answer to the client and saves time keeping the reliability (Slack et al. 2009).

2.5 Costs

It is one of the oldest priorities and more utilized by the companies. Even with the emergence of the other strategies, it still is the most targeted by the businesspersons. Is notorious that the cost is one of the more attractive priorities, mainly because is known the lower the cost of production, the higher the profit. The companies that define the cost as main strategy of production, doing the possible to the cost be always de lower. Slack et al. (2009) remember that all the departments, not only the production affect in the cost. For that is important that all be involved with this objective.

3 Methodology

To answer the purpose objective in the research was necessary the use of data that identify that the competitive priorities the hotels from Sinop, city in the north region of Mato Grosso, has been utilized to obtain advantage in the market. For this, was utilized the qualitative approach as work method and direction. The research also is characterized as exploratory, because pretends identify, analyse and investigate still not comprehended information.

The research was conducted with the five largest hotels in quantity of bedrooms. The sample was defined in this criterion due the identification that the largest part of capacity of accommodation in the city is concentrate in this five hotels, therefore representative of the sector.

The data collect was performed through a questionnaire elaborated with the utilization of Likert Scale. The application of the data collection instrument was done with a researcher, that is, the applicator was present while the interviewed answered the questions. Thus was possible to correct possible distortions in the moment of answers.

4 Results and Discussions

In the quiz there were some asks with the aim of drawing the profile of the researched hotels. In the sequence, it had many prepositions, being rated each one by the hotelier, starting in "nothing important" until "very important". Thus was possible obtain the results and answer the purposed objective.

Referring to the profile of the researched hotels, the research reveals that all have more than ten years of market. Regarding the framework before the Federal Revenue Service, the majority (60%) of them is characterized as Micro business, that by the legislation invoices until R$360,000.00 (three hundred sixty thousand) by year. In relation to the quantity of the researched hotels, is appointed that the most of them (90%) have among 31 (thirty-one) and 60 (sixty) bedrooms. In addition, all the researched was unanimous in affirm that the most part of the demand comes to the business tourism.

The sequence relates the statements presented to the respondent that should opt in the school among "nothing important" until "very important":

01. The holidays are of great importance to the hotel.
02. There is promotion or special price to the holidays.
03. There is a different price to de guests traveling by business.
04. The realization of business events is expressively important to the hotel.
05. The hotel has rooms to meetings and events.
06. The rooms to meetings and events are frequently utilized.
07. The breakfast is available only in the morning period (until 9 o'clock).
08. The breakfast has presents varieties on the menu.
09. The cleaning utilized products are of excellent quality.
10. The electronics in the rooms are of the last generation.
11. The bed sheets, pillows and mattresses are renewed frequently.
12. The governance service is reliable.
13. There is a variety of room types available.
14. There is available parking to the guests.
15. The hotel has laundry service.
16. The hotel has restaurant service.
17. The hotel offers cable TV, internet e quality telephone service.
18. The majority of the accommodations is realized by the booking.
19. There are many leisure options near the hotel.
20. There are accessible prices to attend a class with low income.
21. The internet is free, but contains other types that are paid.

Each item corresponds to a competitive criterion. For example, items 02 and 03 to check about cost, items 10 and 11 relate to quality.

According to the proposed propositions, it is important to highlight some determining results in this article.

The research showed initially the predominance of business tourism, confirming in the answers that, to all the researched hotels, the holidays are little important. A manager, during the quiz application, complemented affirming that the holidays disturb the location of the housing unities.

The events are of big importance to the all hotels, this way they also frighten the relevance in have meeting rooms and events salon. But, they highlight that the rooms are not utilized with so much frequency.

Referring to the breakfast, all the respondents alleged to serve the breakfast only in the morning. One of the managers, when evaluating this preposition, affirmed has already tried to serve the breakfast for more time, but due to de profile of the received public was a big waste. In relation to the variety of the breakfast products, all the hotels demonstrated to be an important factor.

Also was unanimous the hoteliers answer when evaluating the importance of utilization of the excellent cleaning products, last generation home appliances, frequent renovation of the layettes and obtain a confinable governance service. All of them consider very important each cited preposition, which reveals the major concern with the quality by the hotels.

The majority of the interviewed still consider important to offer a variety of kinds of bedrooms, have parking and obtain laundry service to the guests. About the restaurant service, was obtained little importance by the hotels, but they recognize the relevance of obtain a cable TV, internet and telephony service of great quality.

On the question bookings, was identifying that there is not so much relevance to about 40% of the interviewed. The others value the process of the hosting by booking. About leisure options near the hotel, the majority of the hotels pointed negatively, affirming the city still does not have many options to the guests.

Was verified not exist a concern by the hotels in relation the price, being little flexible, do not attending classes with low income. Other factor unimportant is the availability of the internet options to the guests, as faster. All the hotels offer only the traditional that is free.

These were the principal perspectives the research brought through the obtained answers. Each one gave help to the conclusion of the research and de performance of the objective following at the conclusion of this article.

5 Final Considerations

Against the research and analysis, it can be concluding that is many priorities presents in the researched hotels, being they: flexibility, reliability, velocity and quality. The cost priority was inconsiderate, based on the collected data.

However, the priority that more stood out was quality. According to Filho et al. (1995), the quality must contain eight dimensions, being them, velocity, special characteristics, durability, reliability, conformity, technical assistance, esthetical and product image. In front of this, was understood the obtained result in the research, which makes it possible to understand why many possibilities are presents in the researched hotels.

Is important to highlight that the competitive priority flexibility is presented as the second option more present in the researched hotels. Being that it contributes significantly to the attendance of various kinds of guests, which also leads to the quality item.

According to the obtained answer, it can be justified by the demand characterized in the research. Knowing that the county receives mainly business tourists that according to the Ministry of Tourism are demanding customers. This justifies the search of the researched companies by the competitive priority quality. Other possible reason to the presented results can be that the researched hotels are the largest in the city of Sinop.

References

Barros Neto, J. de P., Fensterseifer, J. E., & Formoso, C. T. (2003). Os critérios competitivos da produção: um estudo exploratório na construção de edificações. *Revista de Administração Contemporânea, 7*(1), 67–85. ISSN 1982-7849 (online).

Brasil, Ministério do Turismo (2006). *Meios de Hospedagem: Estrutura de Consumo e impactos na economia* (Relatório Final).

Bortoli Neto, A. (1994). Principais problemas das micro e pequenas empresas. *Estudos Sebrae* (1), 8–13.

Cobra, M. (2001). *Estratégias de marketing de serviços*. São Paulo: Cobra.

Filho, A. G. A., Pires, S. R. I., & Vanalle, R. M. (1995). *Sobre as Prioridades Competitivas da Produção: compatibilidades e sequencia de implantação*.

IBGE Instituto Brasileiro de Geografia e Estatística. Disponível em http://www.ibge.gov.br/home/. Acesso em 01 Sept 2015.

Jacobs, F. R., Chase, R. B. (2012). *Administração de operações e da cadeia de suprimentos*. (13th ed.). São Paulo: Bookman.

Nogueira, E., Filho, A. G. A., & TORKOMIAN, A. L. V. (April 2001). Empresas de revestimento cerâmico e suas estratégias competitivas e de produção. *Gestão e Produção*. Disponível em http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0104-530X2001000100007&lang=pt. Acesso em 22 July 2015.

Porter, M. E. (1989). *Vantagem competitiva: criando e sustentando um desempenho superior* (15th ed.). Rio de Janeiro: Campus.

SECRETARIA DE DESENVOLVIMENTO E TURISMO DO ESTADO DE MATO GROSSO (2010). Turismo, biodiversidade e a força econômica de Mato Grosso. Disponível em http://www.sedtur.mt.gov.br. Acesso em 14 oct 2015.

De Siqueira, J. P. L. (2009). Gestão da Produção e Operações. Curitiba: IESDE Brasil S.A.

Slack, N., Johnston, R., & Chambers, S. (2009). *Administração da Produção* (3rd ed.). São Paulo: Atlas.

Motivators and Barriers for Using Design Thinking in NPD

R. C. Redante, J. F. De Medeiros and C. M. L. Cruz

Abstract Design thinking is an iterative approach that contrasts with the conventional new product development process, which is considered a linear process. The purpose of this study is to look into the use of design thinking as an approach to improve the new product development process by finding the motivators that encourage and the barriers that restrain the use of the methodology in NPD. A systematic literature review was used as method. Some of the main motivators found include an improvement to innovation results and greater understanding by users. The major barriers that may restrain its use derive from the teams' fear of failing and improper implementation. Understanding such factors may help companies that wish to use the approach, or even prevent potential mistakes and giving up.

Keywords Design thinking · New product development · Barriers Motivators

1 Introduction

Design thinking is a topic that has gained considerable attention lately, both in the academia and among practitioners, in a wide range of contexts beyond the traditional field of design (Kimbell 2011). Design thinking is usually related to the process of how designers work, and refers to introducing the design methods and culture beyond their field of work (Gloppen 2009; Chang et al. 2013).

R. C. Redante · J. F. De Medeiros (✉) · C. M. L. Cruz
Faculdade de Ciências Econômicas, Administrativas e Contábeis (FEAC),
Universidade de Passo Fundo, Passo Fundo, RS, Brazil
e-mail: janine@upf.br

R. C. Redante
e-mail: 162864@upf.br

C. M. L. Cruz
e-mail: cassiana@upf.br

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The design thinking process is iterative and moves from generating insights about end users, to idea generation and testing, creating fast solutions through the development of simple prototypes, to the final solution and implementation (Kimbell 2011; Luchs 2015). This iterative process contrasts with the conventional new product development (NPD) process, which is considered linear (Luchs 2015). Through the organizations' skills and resources, NPD creates new products or improves already existing ones (Cooper 2003).

The activities that make up NPD range from defining a technological or market opportunity all the way to commencing production of a product or service and subsequently launching it in the market (Browning and Ramasesh 2007). Understanding the practices that influence NPD success is essential for any company looking to continuously improve their product development processes (Kahn et al. 2012; Nicholas et al. 2011). Also, identifying practices that are able to more efficiently and/or effectively deliver a new product could be significant for the vitality of both the product and company (Barczak and Kahn 2012).

Therefore, through this study we seek to understand the motivators and barriers related to the use of design thinking to, consequently, propose an approach to using the methodology in order to improve the product development process. First off, a systematic literature review was conducted to identify such motivators and barriers, as well as design thinking practices that may be incorporated into NPD, in an effort to examine the fundamental relationships underlying this incorporation and understand how such relationship takes place.

2 Method

A systematic literature review was conducted to understand the advancements in the research on design thinking and the product development process. This type of review provides a reliable basis for decision making and reinforces the legitimacy and authority of the results found (Tranfield et al. 2003). Additionally, the systematic review methodology is explicit and reproducible, and comprises primary studies that clearly state their goals, materials, and methods (Greenhalgh 1997).

In line with the purposes of this study, the systematic review sought to understand the state of the art and research progress in the fields of design thinking and product development process in order to investigate the possible factors that inhibit and facilitate the use of design thinking in NPD, as well as the design thinking practices that may be incorporated into NPD. After the study's guiding purpose had been set, the journals were selected. Regarding the choice criteria, we decided that journals would be primarily searched for in the "Web of Science" and "Scopus" databases, as these bases are internationally renowned and widely used as a research source. Later on, the selection of source magazines for the study considered their titles and scopes. That means the alignment between each publication's focus and its relationship to the purpose of this study was maintained. Hence, a total of 12 magazines dedicated to design, business and management were included as sources of data, as shown in Table 1.

Table 1 Articles found by journals and keywords

Journals	"Design thinking"	Design thinking	"Product innovation"	Product innovation	"Product development"	Product development	"NPD"	Selected articles
Creativity and innovation management	28	506	315	734	411	678	114	7
Design and culture	42	229	0	87	7	204	0	2
Design issues	158	577	38	346	111	593	2	7
Design management journal	45	73	33	80	58	80	8	8
Design management review	217	735	79	619	340	753	16	13
Design studies	282	1198	73	505	246	1058	9	5
Journal of business research	8	2087	316	1539	609	3222	62	2
Journal of product innovation management	27	748	1901	1901	1860	1885	604	28
Materials and design	9	1077	25	451	309	2855	2	0
Project management journal	4	266	87	256	179	331	38	3
Strategy and leadership	48	1030	81	1004	358	1673	6	3
The design journal	85	348	36	242	156	413	18	2
Total								80

In the next phase, i.e. the selection of studies, we searched the 12 magazines using the key words: "design thinking," "product development," "product innovation," and "NPD". Searches were conducted using the key words with and without quotation marks for greater search validity. The key words were used as selection criteria for titles, key words, abstracts, and text bodies. The time limit for the search was not set. After duplicated articles had been excluded, the abstracts of all remaining articles were individually analyzed so that only papers whose research questions and results were directly related to the topics studied were selected. At the end of this phase, the set of publications to be used for the systematic review was cut to 80 papers that actually addressed the main question, and those papers were subsequently analyzed and evaluated. However, when writing this paper, the authors chose to use only a small number of studies, and selected the papers and authors that best suit the topic given their degree of relevance and representativeness in the literature.

3 Motivators and Barriers for Using Design Thinking

One of the main motivators found for the use of design thinking focuses on the possibility of improving innovation outcomes. In the business context, design thinking can be pointed out as an incentive to innovation and growth as organizations face their challenges (Liedtka 2015). The literature on the topic highlights the approach's potential to improve innovation outcomes, be they products, services, or strategies (Mahmoud-Jouini et al. 2016). Therefore, design thinking is a central tool for innovation, especially in organizations seeking to maintain or grow market share, and increase user satisfaction (Kimbell 2011).

Additionally, this way of thinking by designers may allow people to more efficiently identify problems and create solutions (Chang et al. 2013). Therefore, another motivator we found is the ability of design thinking to deal with complex problems. Designers have dealt with open, complex problems for many years (Buchanan 1992; Rylander 2009), and studying how they work, as well as adopting some of their practices, could be interesting for organizations (Dorst 2011). These problems are typically poorly defined and carry incomplete, contradictory, ever-changing requirements (Rylander 2009; Mahmoud-Jouini et al. 2016).

Furthermore, design thinking is essentially a human-centered approach to problem solving, driven by users, and one that counts empathy among its essential values (Kimbell 2011; Liedtka 2015). In view of the foregoing, another motivator that stands out is the possibility of better understanding users through design thinking. A user-centered approach should understand problems from the users' perspective, and throughout the entire development process it must test the assumptions made with actual users (Ward et al. 2009). Hence, it is an approach that seeks to foretell demands and meet users' needs, which oftentimes are not explicit, through intuitive products that are comfortable to use. Therefore, design thinking seeks to deeply understand people, their tastes and needs, and how they see the products and their features, in order to be able to turn these aspects of behavior into value and benefits for companies (Brown 2008).

We also highlight the possibility of testing solutions before taking them to the market as a motivator as well. The prototyping phase in the design thinking process allows for the developed approaches to be tested via simple preliminary models, which do not need to be exact representations of the project but make ideas tangible (Seidel and Fixson 2013). Prototyping is meant to drive experimentation via assumption testing and field experiments in the real world to help with decision-making and continued learning (Liedtka 2015). That means using prototypes in product development lowers risks and improves success rates in the innovation process, in addition to increasing the accuracy of feedback from potential clients. Moreover, prototyping and prior testing help teams believe in the success of the solutions created, and prevent ideas from being tossed out for fear of the unknown (Brown and Martin 2015).

Finally, process humanization stands out as a motivator. In that regard, design thinking can help humanize technology and develop emotionally resonant solutions, considering design thinking is an essential tool for streamlining and humanizing processes (Kolko 2015). Many organizations are steered by an analytic rationale, and in that regard design thinking can become a subjective, emotional alternative (Brown 2008; Rylander 2009). This perspective may help create a workplace where people want to be, one that responds quickly to changing business dynamics and empowers contributors, especially because design thinking is empathetic and tends to implicitly drive a more thoughtful, human approach to business (Kolko 2015).

Fear of failing and running risks stand out as the primary barriers to the implementation of design thinking in NPD. The notion that there is nothing wrong with experimenting and failing, as long as that happens early on, and that failure can be a source of learning, can be a difficult one to accept (Brown and Wyatt 2010). Great design does not come without risk-taking and trying new things, with the very strong possibility of failure (Fraser 2007). A risk-averse culture must learn to accommodate experimentation and occasional failure (Yoo and Kim 2015). Leaders need to create a culture that allows people to take chances and move forward without a complete, logical understanding of a problem (Kolko 2015).

The incorrect implementation of the process by teams has also been found to be a significant barrier. Organizations are being encouraged to adopt design thinking in areas where people may not have prior experience with such methods. If implemented poorly, challenges to adoption may lead to abandonment of a design thinking approach without realizing potential benefits (Seidel and Fixson 2013). Were design thinking to be metaphorically compared to a toolbox, the person using the tools needs to have the knowledge and ability to know when to use them, and is only possible through training (Johansson-Sköldberg et al. 2013).

Another obstacle that can be found is the tension and conflict between team members. Collaboration is at the core of design thinking, which leads to expanded involvement of novice multidisciplinary teams adopting these methods, and the intersection of diverse backgrounds presents a potential for challenge and conflict within the teams preventing them from working together effectively (Seidel and Fixson 2013). According to Micheli et al (2012), new product development is, by definition, cross-functional, and integrating design thinking into NPD is a challenge because industrial designers have very different perspectives and goals than other members of the NPD team, and this can lead to tensions.

Furthermore, process barriers stand out. The way designers work and think oftentimes is not clear to other roles involved in NPD, and the explanations on how the process works can seem chaotic compared to the structured development process (Goffin and Micheli 2010). Additionally, the authors point out that managers have little expertise in integrating design into a NPD process, and designers themselves did not consider how their work could be integrated to such NPD framework. Hence, new products and systems usually require people to change the business models and behaviors in place, which may lead to strong resistance from the people tasked with delivering or running them (Brown and Martin 2015).

Finally, the difficulty of measuring results obtained through design thinking stands out as a barrier. According to Collins (2013), explaining the value of design thinking to business has always been a challenge. There is a difficulty in justifying the advantages of implementing the approach as a method of work because it's hard to measure and evaluate the results and the contribution of design thinking activities as there is no specific instrument for measurement (Carlgren et al. 2016). Therefore, it is important to note that, in order to have an engagement in the adoption of design thinking, a common understanding about the design thinking processes and methods is necessary so that the results obtained by companies can be understood at the end of the process (Collins 2013).

4 Interrelations Between Design Thinking and NPD

Because design thinking is an iterative approach, it contrasts with the conventional new product development process, which is linear. Linear frameworks help explain how the organization and management of NPD processes relate to NPD performance (Mccarthy et al. 2006). However, Cooper et al. (1999) recognize that linear management practices tend to turn out only incremental innovations. Design thinking runs counter to this process because it is iterative, based on abduction and learning through experimentation (Liedtka 2015). For that reason, we propose to enhance NPD by using design thinking practices integrated into the process.

Figure 1 shows the integration between NPD phases and design thinking stages. The main difference is in the process, which becomes continuous as the phases are repeated several times and there is the need for constant monitoring. Users become the central element, considering all the solutions created start from understanding users' needs. Users are engaged from the beginning of the process, and remain so throughout all the phases. Several functional teams are interconnected in every phase, and collaboration and communication are vital for such integration.

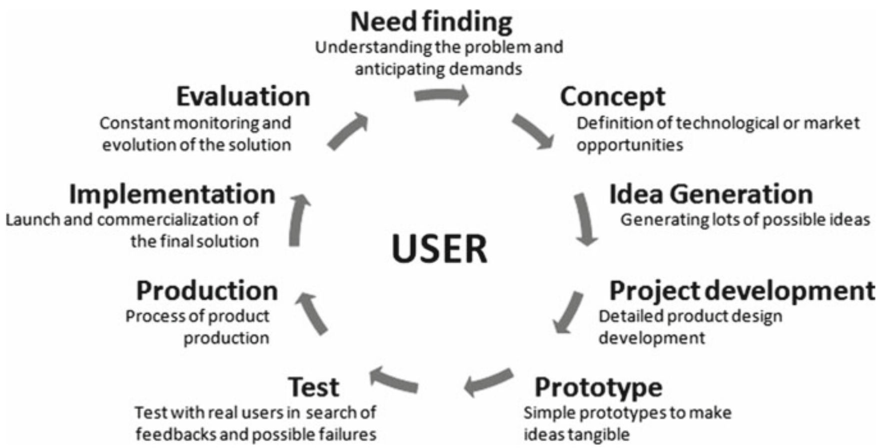

Fig. 1 Integration of design thinking with the NPD. *Source* Elaborated by the authors

5 Final Considerations

Identifying the motivators and barriers to the integrated adoption of design thinking methods in NPD may help companies considering the possibility of adopting them in their processes. Based on data found in the literature, we can highlight the need for multidisciplinary teams to be properly managed so that conflicts do not compromise the use or even implementation of design thinking.

Additionally, for the adoption of design thinking to bring positive impacts, empathy should be one of the core values of the organization (Dalton and Kahute 2016). Therefore, a deeper understanding of users, on which the approach is built, brings companies closer to their audience and may lead to greater demand for the solutions created. Also for that reason, and for testing prior to rollout, the solutions developed based on the integration of the approaches can be very effective, and very innovative as well.

As suggestions for future studies, we propose empirically investigating such motivators and barriers at companies already using the approaches, or planning to. Also, the empirical investigation should be extended for other contexts than the NPD, to identify if the motivators and barriers are confirmed in all contexts. Lastly, we propose some additional empirical investigation about the application of design thinking in the NPD, and about the measurement of the benefits and the results of this application.

References

Barczak, G., & Kahn, K. B. (2012). Identifying new product development best practice. *Business Horizons, 55,* 293–305. https://doi.org/10.1016/j.bushor.2012.01.006.

Brown, T. (2008). Design thinking. *Harvard Business Review, 86,* 84–92.

Brown, T., & Martin, R. (2015). Design for action. *Harvard Business Review, 93,* 56–64.

Brown, T., & Wyatt, J. (2010). Design thinking for social innovation. *Stanford Social Innovation Review.*

Browning, T. R., & Ramasesh, R. V. (2007). A survey of activity network-based process models for managing product development projects. *Production and Operations Management, 16,* 217–240. https://doi.org/10.1111/j.1937-5956.2007.tb00177.x.

Buchanan, R. (1992). Wicked problems in design thinking. *Design Issues, 8,* 5–21. https://doi.org/10.2307/1511637.

Carlgren, L., Elmquist, M., & Rauth, I. (2016). The challenges of using design thinking in industry—Experiences from five large firms. *Creativity and Innovation Management, 25,* 344–362. https://doi.org/10.1111/caim.12176.

Chang, Y., Kim, J., & Joo, J. (2013). An exploratory study on the evolution of design thinking: Comparison of Apple and Samsung. *Design Management Journal, 8,* 22–34. https://doi.org/10.1111/dmj.12001.

Collins, H. (2013). Can design thinking still add value? *Design Management Review, 24,* 35–39. https://doi.org/10.1111/drev.10239.

Cooper, L. P. (2003). A research agenda to reduce risk in new product development through knowledge management: A practitioner perspective. *Journal of Engineering and Technology Management, 20,* 117–140. https://doi.org/10.1016/S0923-4748(03)00007-9.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (1999). New product portfolio management: Practices and performance. *Journal of Product Innovation Management, 16,* 333–351.

Dalton, J., & Kahute, T. (2016). Why empathy and customer closeness is crucial for design thinking. *Design Management Review, 27,* 20–27. https://doi.org/10.1111/drev.12004.

Dorst, K. (2011). The core of "design thinking" and its application. *Design Studies, 32,* 521–532. https://doi.org/10.1016/j.destud.2011.07.006.

Fraser, H. M. A. (2007). The practice of breakthrough strategies by design. *Journal of Business Strategy, 28,* 66–74. https://doi.org/10.1108/02756660710760962.

Gloppen, J. (2009). Perspectives on design leadership and design thinking and how they relate to european service industries. *Design Management Journal, 4,* 33–47. https://doi.org/10.1111/j.1942-5074.2009.00005.x.

Goffin, K., & Micheli, P. (2010). Maximizing the value of industrial design in new product development. *Research-Technology Management, 53,* 29–37.

Greenhalgh, T. (1997). Papers that summarise other papers (systematic review and meta-analyses). *BMJ, 315,* 672–675.

Johansson-Sköldberg, U., Woodilla, J., & Çetinkaya, M. (2013). Design thinking: Past, present and possible futures. *Creativity and Innovation Management, 22,* 121–146.

Kahn, K. B., Barczak, G., Nicholas, J., Ledwith, A., & Perks, H. (2012). An examination of new product development best practice. *Journal of Product Innovation Management, 29,* 180–192. https://doi.org/10.1111/j.1540-5885.2011.00888.x.

Kimbell, L. (2011). Rethinking design thinking: Part I. *Design and Culture, 3,* 285–306. https://doi.org/10.2752/175470811X13071166525216.

Kolko, J. (2015). Design thinking comes of age. *Harvard Business Review, 93,* 66–71.

Liedtka, J. (2015). Perspective: Linking design thinking with innovation outcomes through cognitive bias reduction. *Journal of Product Innovation Management, 32,* 925–938. https://doi.org/10.1111/jpim.12163.

Luchs, M. G. (2015). A brief introduction to design thinking. In: M. G. Luchs, K. S. Swan, & A. Griffin (Eds.), *Design thinking: New product development essentials from the PDMA* (pp. 1–11). New Jersey: Wiley.

Mahmoud-Jouini, S. B., Midler, C., & Silberzahn, P. (2016). Contributions of design thinking to project management in an innovation context. *Project Management Journal, 47,* 144–156. https://doi.org/10.1002/pmj.

McCarthy, I. P., Tsinopoulos, C., Allen, P., & Rose-Anderssen, C. (2006). New product development as a complex adaptive system of decisions. *Journal of Product Innovation Management, 23,* 437–456. https://doi.org/10.1111/j.1540-5885.2006.00215.x.

Micheli, P., Jaina, J., Goffin, K., Lemke, F., & Verganti, R. (2012). Perceptions of industrial design: The "means" and the "ends". *Journal of Product Innovation Management, 29,* 687–704. https://doi.org/10.1111/j.1540-5885.2012.00937.x.

Nicholas, J., Ledwith, A., & Perks, H. (2011). New product development best practice in SME and large organisations: Theory versus practice. *European Journal of Innovation Management, 14* (2), 227–251. https://doi.org/10.1108/14601061111124902.

Rylander, A. (2009). Design thinking as knowledge work: Epistemological foundations and practical implications. *Design Management Journal, 4,* 7–19. https://doi.org/10.1111/j.1942-5074.2009.00003.x.

Seidel, V. P., & Fixson, S. K. (2013). Adopting "design thinking" in novice multidisciplinary teams: The application and limits of design methods and reflexive practices. *Journal of Product Innovation Management, 30,* 19–33. https://doi.org/10.1111/jpim.12061.

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management, 14,* 207–222. https://doi.org/10.1111/1467-8551.00375.

Ward, A., Runcie, E., & Morris, L. (2009). Embedding innovation: Design thinking for small enter-prises. *Journal of Business Strategy, 30,* 78–84.

Yoo, Y., & Kim, K. (2015). How Samsung became a design powerhouse. *Harvard Business Review, 93,* 73–78.

Implantation of Total Productive Maintenance: A Case Study in the Manufacturing Industry

Gleisoon Amorim, Kazuo Hatakeyama and Ximena Rojas-Lema

Abstract The objective of this research was to apply the total productive maintenance analyzing the performance of the autonomous maintenance pillar in a pilot manufacturing industry. The case study used as a procedure with the nature of research as applied quantitative approach. The results showed that even the pillar of autonomous maintenance, being the process of training, in order to make operators able to promote changes in their work environment that guarantee high levels of productivity, it needs the support of the basic pillars. Without them, such pillar would not have the necessary conditions to act in the planning of application of the methodology. The overall equipment efficiency had its value maximized by 30% in two and a half years, indicating that had its productive capacity high, enabling the increase in the organization's revenues.

Keywords Autonomous maintenance · Reliability · Availability Performance

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G. Amorim
Centro Universitario Tupy, Anima/Unisociesc, Joinville, Brazil
e-mail: amorimlogistica@hotmail.com

K. Hatakeyama
Curitiba, Brazil
e-mail: khatakeyama@uol.com.br

X. Rojas-Lema (✉)
Departamento de Estudios Organizacionales y Desarrollo Humano,
Escuela Politécnica Nacional, Ladrón de Guevara, E11-253, Quito, Ecuador
e-mail: ximena.rojas@epn.edu.ec

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1 Introduction

Frequent changes occurred in the economy around the world with the market becoming sensitive to the price, has led increasingly the organizations to attain better results, requiring to search of differentiators in the processes of production that better the performance continuously (Singh and Ahuja 2013).

This work applied the total productive maintenance—TPM and analysed the performance of the pillar of autonomous maintenance—AM, in one pilot sector of manufacturing industry, to verify the indicators of performance of this approach.

2 Maintenance

Shirose (2000, p. 13), "conceptualizes maintenance as the set of activities with the objective to suppress defects of quality produced by damage and eliminate adjustment of equipment". The activities of corrective maintenance characterize by the action of recovering the basic functioning capacity or one failure that occurred in the equipment (Sachdeva et al. 2008). The preventive maintenance consists in actions taken with the intention to keep one or several equipment in operating conditions by repeated maintenance on one interval of the time planned by inspection, prevention of failures, reform and change of parts.

2.1 Total Productive Maintenance—TPM

The TPM proposes the activity of productive maintenance with the involvement of all levels of the company, from the top executive to the last level of operation, seeking for possible betterment of global performance (Chandegra and Deshpande 2014). Pathak (2015), states that the TPM, could establish standards to eliminate losses, reducing maintenance costs by predicting failure through the betterment of quality of personnel and the equipment.

2.2 Stages of TPM Implementation

Nakajima (1989) stated that the TPM normally implanted by twelve stages in the frame of four phases: preparation, introduction, implementation, and consolidation; as described in the Table 1. TPM is a helpful tool to support within the ideal fabrication process. The organization that is capable to achieve this level of maintenance, will gain competitive advantages (Waghmare et al. 2014).

Table 1 The twelve stages of implementation of the TPM

Phase	Stage	Content
Preparation	1. Statement of the top manager towards the decision to adopt the TPM	Divulge about the TPM throughout the organization
		Use of means of communication available (murals, seminars, internal newsletters, etc.)
	2. Campaign to divulge and initial training	Seminars directed to middle and top administration
		Projection of videos to operational personnel
	3. Secretary for implementation of the TPM	Structure of committees for the implementation of the TPM
	4. Basic guidance of the TPM	Objective and its demarcation, results forecasts
	5. Master plan for implementation of the TPM	Design plan of each stage, since the introduction to the consecration
Introduction	6. Take-off of the TPM	Invitation to the suppliers, and affiliated companies
Implementation	7. Build designed organization to maximize the efficacy of the production	Seek the maximum of efficacy in the production
	7.1. Conduct activities of focused improvements	Activities in the project team and small groups
	7.2. Self maintenance	Sequential technique of auditing and confirmation of the approval
	7.3. Planning of the maintenance	Systematic maintenance
		Preliminary maintenance
		Infrastructure management, spare parts, tools, technical drawings
	7.4. Operational training of maintenance and of license	Collective training of the leaders;
		Training of members and creation of communication links
	8. Structure to control and equipment management in a given phase of the operation	Develop products and equipment that are easy to use
	9. Build one maintenance quality system	Establish, maintain and control the conditions for zero defect
	10. Build one efficacy management system	Increment efficacy to support production; Improve and simplify administrative functions and office environment
	11. Develop the management system to manage safety, health and environment	Ensure the environment free of accidents and pollution
Consolidation	12. Realization of the TPM and its improvement	Candidacy to the TPM prize,
		Seek for more ambitious objective

Source Adapted of Suzuki (1993)

Table 2 Development of the TPM columns

1st generation (Focus in the equipment)	2nd generation (Focus process/production)	3rd generation (Focus in the company)
1. Improvement of the efficiency of the equipment; 2. Propose autonomous maintenance to the operator; 3. Planned maintenance; 4. Training to better the operation and the maintenance of competencies; 5. Initial control of the equipment;	1. Improvement of the efficiency of the equipment; 2. Propose autonomous maintenance to the operator; 3. Planned maintenance; 4. Training to better the operation and maintenance of competencies; 5. Initial control of the equipment; 6. Improvement of the support department (quality)	1. Improvement of the efficiency of the equipment; 2. Propose autonomous maintenance to the operator; 3. Planned maintenance; 4. Training to better the operation and maintenance of competencies; 5. Initial control of the equipment; 6. Improvement of the support department (quality); 7. TPM in the administration; 8. Safety, hygiene and environment

Source Chandegra and Deshpande (2014)

2.2.1 Basic Pillars to Support TPM

Lazim et al. (2008) suggested the implementation of TPM following 8 pillars. Table 2 show them.

2.2.2 Performance Indicators

Performance measurement is a process of quantify the action, insofar the measurement is the manner to quantify and action related to performance, involving two variables: efficiency and efficacy (Chaves and Callado 2014).

Rhee and Ishii (2004), describe that most utilized are: the mean time between failures—MTBF or the average time of operations between failures and the mean time to repair—MTTR or average time to repair. Therefore, the study focused in metrics OEE, as the indicator to measure the quantitative way the global performance of the assets in operation, having the basis for estimation the formula 1.

$$\text{OEE} = \text{performance} \times \text{quality} \times \text{availability}. \quad (1)$$

3 Methodological Procedures

This research utilized the procedure of case study based on manufacturing industry. As the approach the survey is quantitative and descriptive, the data collected are from the indicators of industrial performance and the TPM spreadsheets. The instrument utilized for the data collection, the non-participant systematic observation and documentary survey. The sample applied was of inductive type, selected by the importance of the actors. The survey developed in manufacturing industry, named as enterprise "A". The data were collected from the end of period of 2013 to the middle of 2016, including only the pillars of autonomous maintenance—AM, specific improvement—SI, planned maintenance—PM, education and training—EDT, also created the pillar of problem solving management—PSM, which were the basic pillars that the enterprise deemed necessary to implement in the manufacturing plant.

4 Analysis of the Results

The EDT, qualified the team of the TPM, qualifying operators in conditions to make minor repairs and adjustment in equipment, thus releasing the maintenance technicians to plan and solve more relevant anomalies of equipment, and also to meet the schedule of the preventive maintenance/planned. The EDT is the basis for the others pillars to happen.

In the year 2014, when the implementation of the TPM started, the indexes of application of education and training were not acceptable, having low performance in the indicators. In 2015, with the actions established by the pillar of the EDT, the indexes of application obtained relative improvement regarding to the previous year. In 2016, the actions established by the pillar of the EDT, were matured, therefore, persons involved in the process understand the true importance to have the commitment with their qualification, with that, the indexes of application obtained the planned results and expected of 100% realized, it worth to highlight that it was measured solely until July of that year.

With the investment in maintenance, increased the cost, aiming to reduce failures, increase the availability, reduce the MTTR, increases the quality and the MTBF. Initially sought to maintain or guarantee the availability of equipment during the time that programmed to work, with lowest cost as possible. The following figures describe preliminary results of the implementation of the TPM.

The total time estimated over 24 h shift per day. For the time available, must consider the hours for meals of the three shifts (3 h) totalizing 21 h/day. Must consider 22 days (5 days per week = 40 h $\times$ 4 weeks). To complete 44 h weekly, will lack 16 h in the month. Thus if works 2 Saturdays alternatively to compensate this 16 h, thus 4 $\times$ 44 = 176 h, being the base for estimation of the availability in the month (time available).

Where TD: Time available; T: shift; H: hour

$$\text{Time available} = 3\ \text{shift} \times 176\ \text{h} \tag{2}$$

The preventive maintenance/planned, programmed versus conducted, started from 15% in the year 2014, to 98% of execution in the year 2016, exceeded the planned percentile. The availability of machine had significant increase (Fig. 1).

Figure 2 describes that in the beginning of the implementation of the TPM, the average of break of machine had a reduction of 15% (77.9 h) in 2014, to 3.0% (15.6 h) in 2016, confirming the increase of the availability of the machine, as the less break occurs, more time the equipment stay in operation. However, had a significant increase from \$150,000.00 to \$610,000.00, in the cost of maintenance, due to self-consumption of replacement parts and man power, because before the implementation of the TPM, the equipment affected much with the depreciation by the lack of planned and periodical actions of maintenance.

With the investments in the maintenance and with the implementation of the TPM, the index of performance increased from 77% in 2014 to 91% in 2016. The analysis of the indicator of quality showed the elimination of the rework, which in the year 2014 obtained 15 units, in the 2016 this index was zero (Fig. 3).

In the Fig. 4, the MTBF, relates directly with the reliability, even taking an increase of 87 h of regular functioning of the equipment from 2014 to 2016. Considering the month's average in 2014, machine had stopped 5.08 h/month, such result came from the estimation 519/102. In the year of 2015, the average reduced to 3.39 h/month. In 2016, until July the partial average had 2.74 h of stoppage. In the analysis of the indicator of the average time to repair—MTTR, can see, that had the minimization of the repair time of the equipment/machine, initiated in the year 2014 in 17 h reducing to 9 h in 2016.

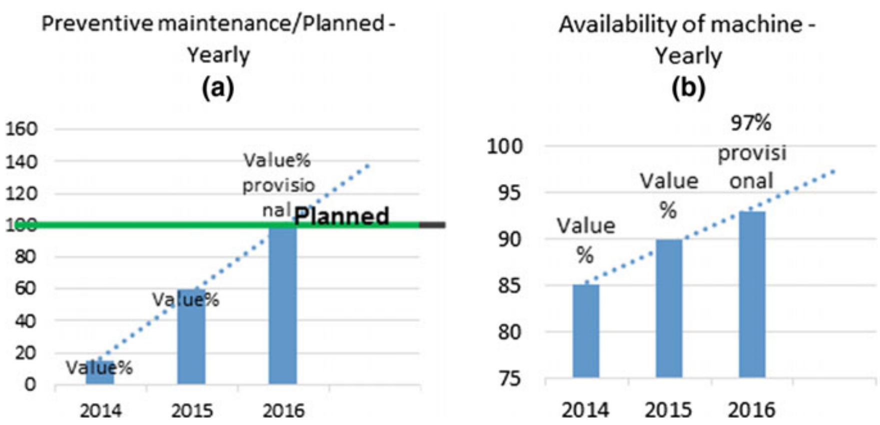

Fig. 1 Preventive maintenance/planned (**a**) and availability (**b**)

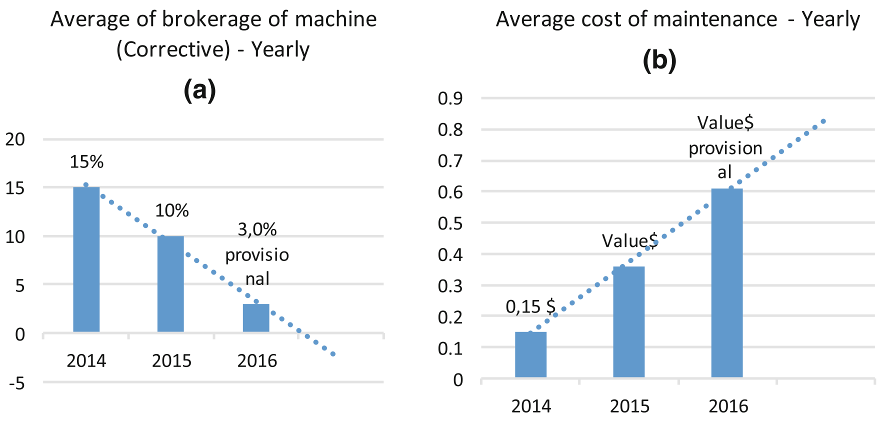

Fig. 2 Corrective maintenance (**a**) and cost of maintenance (**b**)

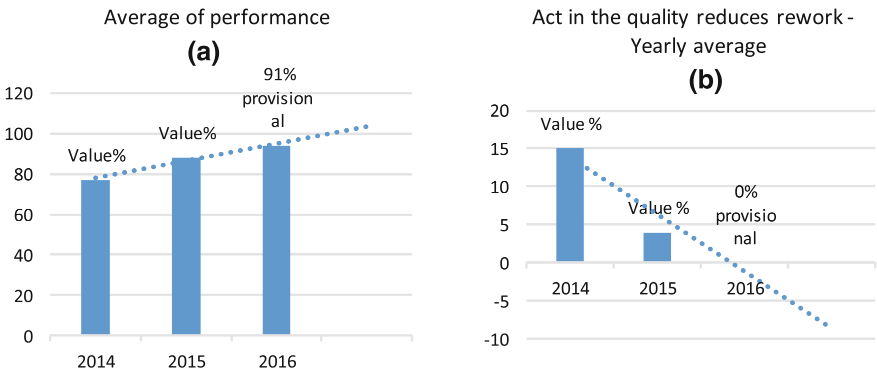

Fig. 3 Performance (**a**) and quality (**b**)

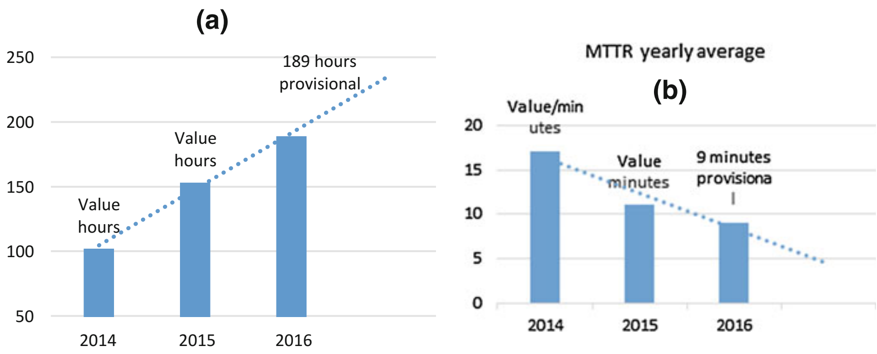

Fig. 4 MTBF (**a**) and MTTR (**b**)

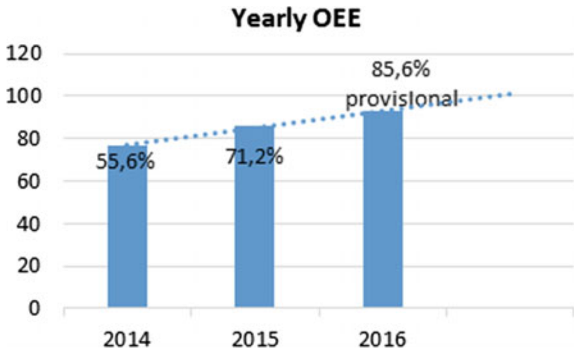

Fig. 5 Overall equipment efficiency

In the year of 2015, the average reduced to 3.39 h/month. In 2016, until July had the partial average has 2.74 h of stoppage. In the analysis of the indicator of average time to repair—MTTR, can see, that had the minimization of the time of repair in the equipment/machine, initiated in the year of 2014 in 17 h reducing to 9 h in 2016.

Figure 5 shows the indicator of the overall equipment efficiency—OEE that started from 55.6% at the beginning in 2014 to 85.6% until July of 2016.

It is worth mentioning that the final figures are partials, as the TPM takes from 3 to 5 years for the maturation, although the company implemented on own way, even so, the planned for such maturity, is within the time suggested by Nakajima.

5 Conclusions

The pillar AM with the proposal to become fit to promote in the work environment changes that guarantee high level of productivity, it requires the aids of the basic pillars, as without them, such pillar will not have necessary conditions to act in the planning of the implementation of the TPM methodology. As the result of the implementation of the TPM, the most relevant indicator of the equipment/machine the OEE, had its value maximized in 30% in two and half years, indicating that had productive capacity increased, making possible the increase in the revenue of the organization.

References

Chandegra, P., & Deshpande, V. A. (2014). Total productive maintenance implementation through different strategies: A review. *International Journal of Advance Engineering and Research Development, 1*(11), 117–128.

Chaves, R. P., & Callado, A. A. C. (2014). *Ciência da Administração, 20*(1), 80–105.

Lazim, H. M., et al. (2008). Total productive maintenance and performance: A Malaysian SME experience. *International Review of Business Research Paper, 4*(4), 237–250.

Nakajima, S. (1989). *Introdução ao TPM—Total productive maintenance*. São Paulo: IMC.

Pathak, S. S. (2015). TPM implementation to fine-tune manufacturing performance: An Indian industrial way. *International Journal of Business Quantitative Economics and Applied Management Research, 1*(8), 71–82.

Rhee, S. J., & Ishii, K. (2004). Using cost based FMEA to enhance reliability and serviceability. *Advanced Engineering Informatics, 17,* 179–188.

Sachdeva, A., Kumar, D., & Kumar, P. (2008). Planning and optimizing the maintenance of paper production systems in a paper plant. *Computer and Industrial Engineering, 55*(4), 817–829.

Shirose, K. (2000). *TPM total productive maintenance new implementation program in fabrication and assembly industries* (4th ed.). Tokyo: Japan Institute of Plant Maintenance.

Singh, K., & Ahuja, I. S. (2013). Synergistic suitability of transfusion of TQM-TPM for Indian manufacturing industries using fuzzy-based model simulation. *International Journal of Business Continuity and Risk Management, 4*(1), 36–46.

Suzuki, T. (1993). *TPM—Total productive maintenance*. São Paulo: JIPM & IMC.

Waghmare, S. N., et al. (2014). Failure mode effect analysis and total productive maintenance: A review. *International Journal of Innovative Research in Advanced Engineering, 1*(6), 183–203.

Analysis of Water Consumption in Cosmetic Factories in Brazil

Sabrina Gonçalves and Carlos Rogério Cerqueira

Abstract The cosmetics industry demands large amount of water: for this reason, companies have implemented strategies to reduce consumption. A comparative study among three companies located in Brazil showed that the use of clean-in-place routine was the strategy that led to a more significant reduction in water consumption.

Keywords Water saving · Cosmetic industry · Environment · Clean-in-place

1 Introduction

Brazil is the fourth-largest beauty market in the world, after the USA, Japan and China. The country accounts nearly for 10% of the global market and was worth more than US$ 31 billion in 2015 (ABIHPEC 2015). The cosmetics industry demands a large amount of water, mainly used in product incorporation and equipment hygienization, the latter being the process that consumes more water.

2 Objectives

The objective of the research is to compare initiatives aimed at optimizing water consumption in the cosmetics, personal hygiene and fragrances sector in three companies with different profiles: *Natura Cosméticos* (Natura), *O Boticário* (Boticario) and *Unilever*. The first two are Brazilian cosmetic companies, while the

S. Gonçalves · C. R. Cerqueira (✉)
Escola Superior de Engenharia e Gestão, ESEG, São Paulo, SP 04101-000, Brazil
e-mail: carloscerq@gmail.com

S. Gonçalves
e-mail: srgoncalves2@gmail.com

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latter is a transnational company which operates in the Brazilian market. Annual Performance Reports served as database for the analysis.

3 Methods

The analysis was based on the Annual Performance Reports and Sustainability Reports published by each company. It was possible to obtain quantitative data about water consumption in the manufacturing processes, how the wastewater treatment is done and the consumption reduction strategies used in each company.

4 Results

Since 2008, Natura presented a great consumption in its factory destined to the production of shampoos, liquid soaps and creams. The most used operation for sanitizing the equipment is the "*cleaning in set-up's*" (cleaning and sanitizing operations of tanks for preparation and manufacturing of cosmetics and also tanks for storage and transfer of products). It was observed that between 2013 and 2015, there was an increase in water consumption of around 10% per year per unit of product, indicating a deterioration in the water consumption scenario (Natura 2016).

Boticario company presented a reduction of 56% in water consumption from 2009 to 2012 with the implantation of *clean-in-place* (CIP) technique for the sanitization of tanks. The CIP system is a method used for cleaning manufacturing equipment consisting of several recirculating wash cycles through tanks, pumps, valves and other equipment (Boticario 2013). This program ensured a significant reduction in water costs, justifying the cost of implementation.

It was found that reuse and recycling are widely used methods at Unilever. However, this did not imply a significant change in water consumption (1.19 m^3 per tonne of product in 2011 to 1.21 m^3 per tonne of product in 2012) (Unilever 2013).

5 Conclusion

Comparing the three cases, it can be concluded that the CIP technique is more efficient in terms of reducing the consumption of water in the manufacture of cosmetics. Thus, the inclusion of this cleaning routine in the productive process was the strategy of greater effectiveness in reducing water consumption compared to other strategies implemented in the cosmetic industry.

References

ABIHPEC. (2015). Annual report. Cited March 02, 2017. Available: www.abihpec.org.br/anuario-2015.

Boticario. (2013). Sustainability report. Cited March 02, 2017. Available: http://cebds.org/wp-content/uploads/2014/02/relatorio-todos-capitulos2012.pdf.

Natura. (2016). Sustainability report. Cited March 02, 2017. Available: www.natura.com.br/sites/default/files/ra2015_cadernoindicadores_natura.pdf.

Unilever. (2013). Sustainability report. Cited March 02, 2017. Available: www.unilever.com.br/Images/relat-rio-de-sustentabilidade-2012_tcm1284-461456_pt.pdf.

Analysis of the Results of Lean Manufacturing Implementation in a Metal-Mechanical Company from Panambi–Rio Grande do Sul–Brazil

G. E. Guimaraes, F. Schmidt, V. Benetti, L. C. S. Duarte and R. Monaro

Abstract Japanese industries had been developed quality improvement programs since the 1950s, developing long terms in Quality Engineering. Considering A3 Thinking and following Toyota's original idea, every business problem can and should be captured on a single sheet of paper. Therefore, a case study was carried out in company located at Panambi, RS–Brazil. The first step was a pilot project in a specific product line, with the objective of knowing the Lean philosophy. After the results of this step, the method developed for the implementation of the Lean philosophy were structured in projects with a duration from 10 to 12 months, conducted by a multidisciplinary team. At the end, it is noted that the company has expanded and implemented the Lean philosophy for 25% of its production lines and 10% of its employees have already qualified for participation in any of the 11 projects developed over the last 3 years.

Keywords Improvements · Lean manufacturing · A3 · Lean thinking Kaizen · VSM

G. E. Guimaraes (✉) · L. C. S. Duarte
Engenharia de Produção, CCHS, Universidade de Cruz Alta, Cruz Alta, RS, Brazil
e-mail: geduardo@unicruz.edu.br

L. C. S. Duarte
e-mail: duarteluiz16@gmail.com

F. Schmidt · V. Benetti
Bruning Tecnometal Ltda, Panambi, RS, Brazil
e-mail: fabricioschmidt@gmail.com

V. Benetti
e-mail: vanderlei.benetti@bruning.com.br

R. Monaro
ETECON Soluções e Treinamentos, Santa Bárbara d'Oeste, SP, Brazil
e-mail: prof.renatomonaro@gmail.com

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1 Introduction

The Toyota factory in Japan pioneered the development of the term Lean Manufacturing. However, quality management as we know today, just had its recognition with the creation of the term "Total Quality Management" by Edwards Deming and Joseph M. Juran in 1950's (LINS 2000).

From them, other researchers have developed different tools to improve industrial productivity, increase production capacity, reduce waste, increase profits, and reduce variability, among other reasons.

Lean concepts showed excellent results in industry since its birth in the 1950s, with the development of the Toyota Production System.

The company in which the present work was developed works in the metal mechanic sector, with the manufacture of auto parts applied to cars, trucks, buses, tractors and harvesters for several assemblers of the agricultural, road and civil construction segments.

This company started its Lean journey in 2013 as the intention to develop a structured and systemic program to improve the productivity of its manufacturing processes.

The work presented is a kaizen developed during a Lean project, with the aim of improving the stability and quality performance of a manufacturing process of a certain component.

1.1 Theoretical Review

The term A3 refers to a sheet known in international standards of size 29.7 cm by 42 cm, however, in companies working within the Lean philosophy, the term means much more.

Toyota's original idea was that every business problem can and should be captured on a single sheet of paper. This enables all those involved with the problem to see from the same point of view. Although the basic idea is the same in producing an A3, the specific format and content is flexible and most organizations adjust the model to suit their particular requirements (Shook 2008).

The elements of A3 are chained together in a natural and logical sequence. On a single page, an A3 usually includes the following elements:

- Title: defines the problem or theme;
- Responsible/date: identifies the person responsible and the date of the last review;
- Context: establishes the context of the business and the importance of the problem;
- Current conditions: describes the current situation of the problem;
- Objectives/goals: identifies the desired result;

- Analysis: analysis of the situation and the underlying causes that created the gap between the current state and the desired result;
- Proposed countermeasures: some corrective actions are proposed to address the problem and achieve the objectives;
- Plan: indicates a plan of action of who will do what and when to achieve the goal;
- Follow-up: creates a process of review, follow-up and learning, anticipating remaining problems.

Building and discussing an A3 forces individuals to observe reality, present facts, propose preliminary solutions, obtain agreement, and follow-up with a verification and adjustment process, in view of real results.

As a result, A3 is a powerful tool for problem solving and improvement. More than that, A3 is a visual manifestation of a conceptual problem-solving process that involves ongoing dialogue between the person in charge of a problem and others in the organization. Thus, A3 is a fundamental management process that enables and stimulates learning through the scientific method (Shook 2008).

2 Methodology, Actions and Results

2.1 Methodological Approach

The method used in this study was the qualitative case study. The case study documents and analyzes in detail the activity of a company or organization or a part of it.

According to Cauchik and Sousa (2012), a case study is defined as "an empirical work investigating a given phenomenon in a real contemporary context through deep analysis of one or more objects of analysis (cases)." On the other hand, according to Yin (2001), the case study is considered adequate when it comes to an empirical investigation of "how" and "why" on a number of recent events on which the researcher has little or no control.

The first step was a pilot project carried out in a specific product line, with the objective of knowing the Lean philosophy and structuring the method to be adopted for Lean expansion in the other production lines of the company. The results obtained in the pilot project were very satisfactory, such as 49% improvement in productivity, 66% reduction in product scrap and 52% reduction in Lead Time.

Thus, the method developed for the implementation of the Lean philosophy in the company is structured in projects with a duration from 10 to 12 months, conducted by a multidisciplinary team of several departments. This team receives several trainings related to Lean tools and methods, such as Value Stream Mapping, A3 Thinking, Daily Management, Continuous Flow, Leveled System, among others. After the training, this team is responsible for developing and implementing the kaizens needed to achieve the results planned at the beginning of the project.

The Company calls this standard of project management as "learning by doing", which combines training and practical activities.

Currently, the company has expanded and implemented the Lean philosophy for 25% of its production lines, where 10% of its 1700 employees have already qualified for participation in any of the 11 projects developed over the last 3 years.

2.2 *Case: Rework Reduction of the "ENGATE" Assembly (A3)*

2.2.1 Context and Current State

The following aspects were noted to contextualize the case study:

- Low productivity: high part production time due to rework: approx. 40 min/piece;
- High rejection rate of the "Engate" family: 51% of the parts are disapproved at PV1 and EV inspection during the period analyzed: Jan to Mar/2015, as shown in Fig. 1;
- Need for extra welders to meet customer demand: planned cell with 3 operators, but currently there are 4 fixed operators to meet demand, as well as a help chain with 2 other operators to assist in rework, as shown in Fig. 2;
- Existence of 5 Non-Conformity Reports open for "Engate" at the time of information gathering.

2.2.2 Objectives and Goals

Once problems were contextualized, the objectives and goals were defined as:

- Reduce rework time from 40 min/piece to 10 min/piece, improving weld quality;
- Reduce number of defects from 51 to 30%;

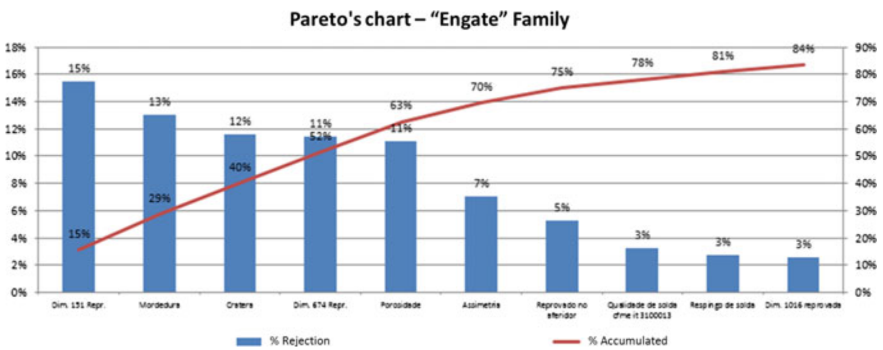


Fig. 1 Rejection graph in PV 1 and EV

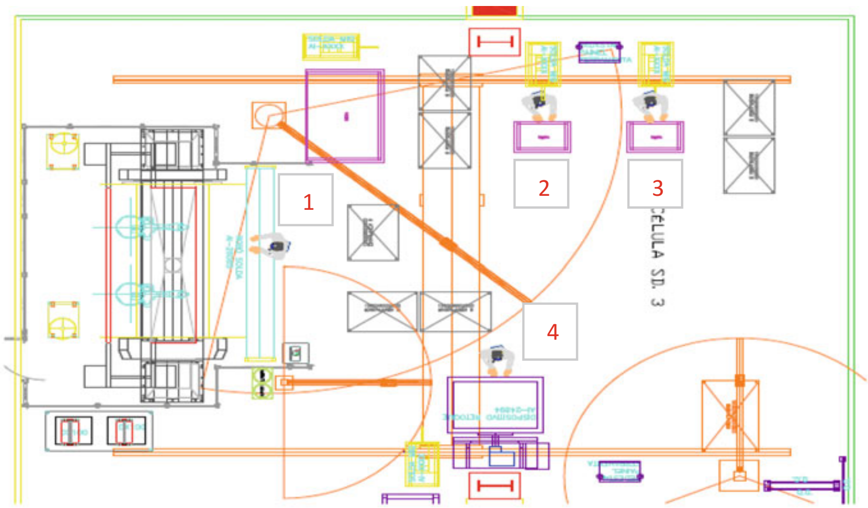


Fig. 2 Current status with 4 operators

- Review processes, train operators, establish new procedures;
- Improve productivity rate from 4.4 to 3.3 Man-Hour/piece (reduce one person in the cell).

2.2.3 Analysis

After all the information was collected, all sectors and processes were analyzed, as follows:

1. Welding Robot
   - Solder less program;
   - Robots with crooked and flamboyant tables;
   - Dirty wire feed system causes weld defects.
2. Welding
   - Cutting oxide hinders welding;
   - Excessive gap between components;
   - Weld height outside specified.
3. Components
   - Parts out of tolerance;
   - Cut imperfections;
   - Tolerances permitted in technical drawing do not meet welding conditions.

4. Templates
   – Worn generating gaps;
   – Backrests out of position;
   – Inefficient tightening.
5. Dimensional
   – Calibration system is not used;
   – Lack of wiring for operators;
   – Inexperienced operators do not calibrate correctly.
6. Layout
   – Inadequate productive flow, poorly used space and planned flow could not be achieved;
   – Lack of portable tools at work stations (sanders, magnets, screwdrivers).

2.2.4 Future State

The objectives and goals set for the future state of the study company were:

- Reduce retouch time to 10 min/piece;
- Reduce number of defects to 30% in PV1 and EV;
- Reduce the number of employees to 3 people in the cell.

2.2.5 Monitoring of Indicators

All results were organized in Table 1 and Fig. 3 in which is possible to see the evolution of the numbers during the next period from Apr to Jun/2015.

Table 1 Results obtained during the case study

Description	Follow-up frequency	Actual	Future	Monthly monitoring			
				Apr	May	Jun	Jul
EV rejection (%)	Daily	50.7	30	49	58	**43**	#
PV 1 rejection (%)	Daily	51.3	30	50	56	**31**	#
Number of operators	#	4	3	4	4	**3**	#
Rework time (min/piece)	Daily	40	10	14	7.5	**1.5**	#

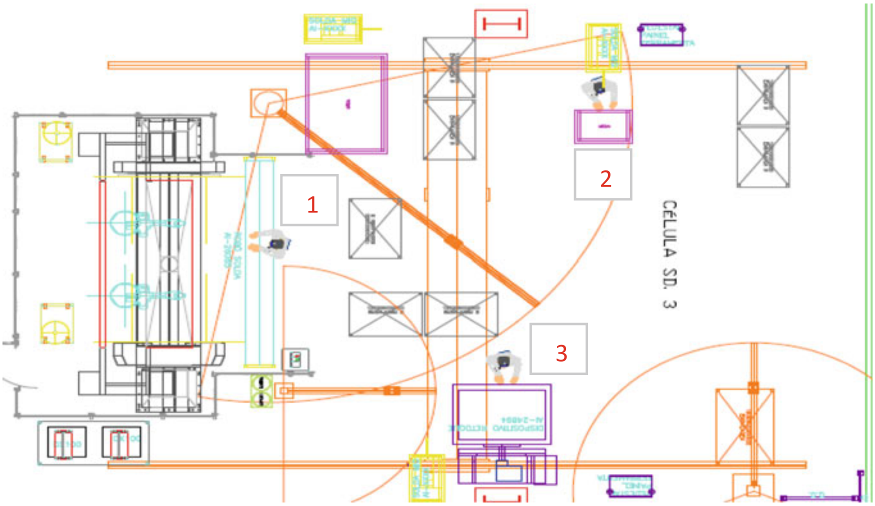


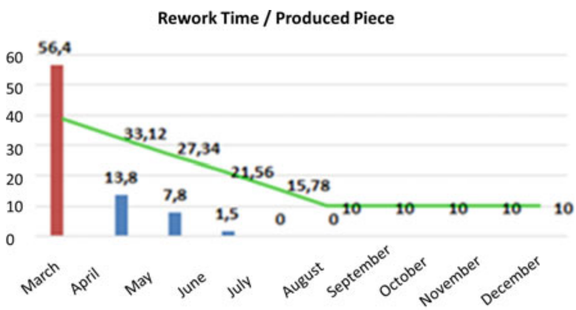
Fig. 3 Future state with 3 operators

2.2.6 Final Results

From the numbers and analysis presented on Table 1 and Fig. 3 it is possible to present the following results for this study:

- The process had 40 min of rework of the weld beads that were realized by the robot in the "sandwich". The goal was of 10 min and with kaizen was achieved, on average, 1.5 min per piece, as shown in Fig. 4;
- There was a reduction from 4 to 3 operators, as planned, as shown in Fig. 5;
- The rebate index of quota 151 was reduced by 40%;
- The bite failure rate was reduced by 84%;
- The crater rejection rate was reduced to ZERO;
- The rejection rate of quota 674 was reduced by 54%;
- The porosity index increased by 0.03%.

Fig. 4 Rework time/ produced piece



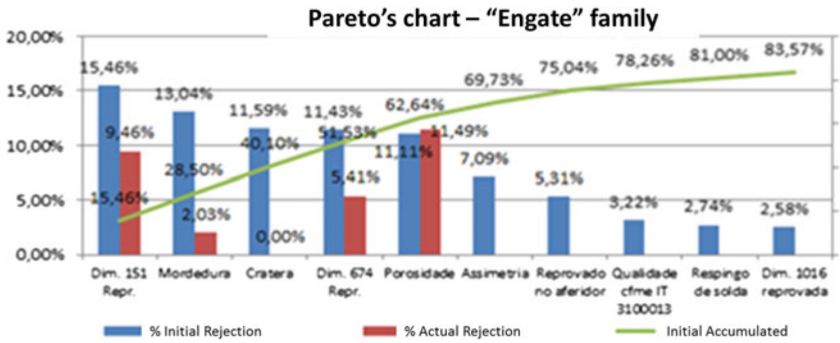


Fig. 5 Rejection graph in PV 1 and EV (Current)

3 Conclusions

The kaizen developed during the Lean project, based on the information and action plans defined in A3, aiming to improve the stability and quality performance of the manufacturing process proved to be totally satisfactory and met all the established goals and objectives.

The results show that the Lean philosophy is already well disseminated in the organization, so that employees can understand the tools and methodologies well, allowing the objectives to be achieved.

We can clearly observe this in the results: a decrease in the number of operators, a decrease in rework time, a decrease in reprobation and rejection rates.

References

Cauchik, P. A. M., & Sousa, R. (2012). Metodologia de Pesquisa: Em Engenharia da Produção e Gestão de Operações. 2ª Edição, Editora Campus.

Kaizen Institute Brasil. (2014). Disponível em <http://br.kaizen.com/home.html>. Acessado em 11 mai. 2014.

Rother, M., & Shook, J. (2003). *Aprendendo a enxergar: mapeando o fluxo de valor para agregar e eliminar o desperdício*. São Paulo: Lean Institute Brasil.

Shook, J. (2008). *Managing to learn: Using the a3 management process to solve problems, gain agreement, mentor and lead*. Cambridge: Lean Enterprises Inst Inc.

Part V
Knowledge and Project Management

Design of a Model for the Analysis of Hidden Costs in International Projects. Application to the Energy Sector

P. Villa, M. Grijalvo and M. J. Sánchez

Abstract The extra costs (hidden costs) incurred in international engineering projects are an element of great relevance from the perspective of project management. These costs have been analysed generally from case-specific perspectives, being necessary the development of a theoretical model that contemplates these hidden costs studying and explaining their nature. In this sense, it is interesting to take advantage of the growing literature on hidden costs associated with offshoring experiences (and originated in the new reshoring trend). Those offshoring experiences have great similarity with international projects as the problems faced come from the same international-related factors. Thus, this paper explores into that literature developing a theoretical model for the analysis of hidden costs applicable to international engineering projects. The model is based in the analysis of the causes of those costs, the processes affected and the final impact on performance. It is finally contrasted and validated with its application to three real cases of three international projects developed by companies of the energy sector. The model is this way proved to be a suitable theoretical basis for the study of hidden costs in international experiences, and the starting point for the definition of risk analysis models to prevent these costs.

Keywords Hidden costs · Internationalization · Risk management
Offshoring · Engineering projects · Energy sector

P. Villa (✉) · M. Grijalvo · M. J. Sánchez
Dpto. de Ingeniería de Organización, Administración de Empresas y Estadística,
Universidad Politécnica de Madrid, C/José Gutiérrez Abascal, 2, 28006 Madrid, Spain
e-mail: pablo.villa.sanchez@alumnos.upm.es

M. Grijalvo
e-mail: mercedes.grijalvo@upm.es

M. J. Sánchez
e-mail: mariajesus.sanchez@upm.es

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1 Introduction

Hidden costs (extra costs) are a key aspect to take into account from the perspective of project management (Larsen et al. 2012). This issue is even more remarkable when those projects are international, this is, projects developed in international locations from the perspective of the companies developing them. Understanding the nature of these unexpected costs is necessary in order to be able to face them in new projects by means of a correct risk analysis that prevents these to appear.

This same problem is faced in many other domains of internationalization, particularly in the case of offshoring. So much so, that the prior offshoring tendency is now being reversed as many companies that had previously offshored are taking those activities back to their country of origin. This process (known as *reshoring/ backshoring*) has become the object of study for many researchers that are trying to explain it. One of the most relevant aspects they point out as a reason of this trend-change is the impact of these hidden costs, originated by factors related to the international nature of offshoring. These costs, defined as those expenses incurred in the implementation of offshoring that were not provided in the previous strategic decision making (Larsen et al. 2012) find great similarities with the hidden costs faced in international engineering projects. This is mainly due to the fact that these types of project are usually carried out by a firm's office outside the geographic jurisdiction of the company's headquarters (where the project is located) which operates as an offshored unit.

This analogy allows us to take advantage of the experiences analysed in the study of hidden costs in offshoring, in order to address the problem of hidden costs in international engineering projects. To this end, it is crucial to develop an analysis model that enables the classification and understanding of these costs, contemplating the unexpected problems faced, the processes affected by these problems, and the final impact in performance that leads to extra expenses. This general unified model that allows the study of hidden costs is a gap in the existing literature as these extra expenses are being analysed in a more case-specific way. In this sense, it is interesting to analyse the growing number of articles dedicated to this issue around offshoring experiences. Once the model is developed, an appropriate validation of it by its application to real engineering projects is needed.

Thus, the article will address the definition of the model for the analysis of hidden cost and the practical application of the model to the projects.

The theoretical study consists on the definition of a model of classification for the hidden costs based in offshoring literature. The literature study begins with the review of about 250 publications (books, academic journals, etc.) using the database of KTH University, *KTH Primo*. From these, about 40 were finally used to give contents to the project (Villa 2016) while in this paper are only presented the main key references. Through the study, three stages have been defined for studying the hidden costs: causes, processes affected and impact in the operational performance. After that, and through the inquiry of the connections existing between those levels, the theoretical analysis is concluded with the definition of the theoretical model. Then, the case studies evaluate the validity of the model through its application to three real engineering projects, studying the hidden costs in them and obtaining relevant conclusions related to the sector of the companies considered. In the three selected cases the companies belong to the energy sector and the projects were carried out in international locations.

This paper is part of a larger work developed during a study stay at KTH and concluded in the UPM, included in the project *Costes ocultos en procesos deslocalización. Aplicación al sector energético*. (Villa 2016). It will begin detailing the methodology used, after what the theoretical analysis, consistent on the literature study and the definition of the model, will be exposed. Later, the case studies on the energy sector are presented, leading to the final conclusions.

2 Literature Study

As commented above, a three-level classification has been established to dissect the hidden costs, heeding the unseen problems that motivate them (causes of hidden costs), the processes affected by those unexpected problems, and the final impact on the operational performance of the company. These three levels, along with the subcategories in each of them, have been established after the analysis of the existent literature on the topic discussed.

By *causes of hidden costs* we refer to those factors that justify the appearance of problems that lead to hidden costs in its resolution. This is, this level gathers the main sources of unexpected costs in offshoring experiences. Seven principal causes of hidden costs have been identified in the literature reviewed (Table 1).

The second level (*processes affected*) includes those processes performed in every firm that are eventually affected in offshoring. The aforementioned causes hinder the proper development of these processes, thus affecting the operational performance of the company. Table 2 exhibits the processes that have been determined based on the existing literature.

The drawbacks experienced in those processes results in an impact to the firms' performance. These possible impacts are encompassed in this last level of analysis

Table 1 Causes of hidden costs

Language	Matloff (2005), Stringfellow et al. (2008)
Cultural differences	Deutsch (2014), Stringfellow et al. (2008)
Employee skills	Matloff (2005)
Geographic distance	Ceci and Prencipe (2013), Stringfellow et al. (2008)
Time difference	Matloff (2005), Ceci and Prencipe (2013)
Complexity	Larsen et al. (2012), Stringfellow et al. (2008)
Level of technology	Acemoglu and Dell (2010)

Table 2 Processes affected

Coordination	Ceci and Prencipe (2013), Matloff (2005)
Control	Jensen et al. (2013)
Specification and design	Deutsch (2014), Jensen et al. (2013)
Product manufacture/service delivery	Gray et al. (2011)
Innovation	Lewin et al. (2009)
Knowledge transfer	Jensen et al. (2013)

Table 3 Impacts on the operational performance

Quality	Gray et al. (2011), Matloff (2005, 2011), Neely (2011)
Dependability	Neely (2011), Slack et al. (2010)
Speed	Neely (2011), Slack et al. (2010)
Flexibility	Neely (2011), Slack et al. (2010)
Cost	Neely (2011), Slack et al. (2010)

(*impacts on the operational performance*), associating them to the five performance objectives par excellence (Table 3).

It is relevant to understand that the hidden cost is the final expense incurred for solving each operational performance problem (e.g. an unexpected quality problem that is solved spending extra money in new technology).

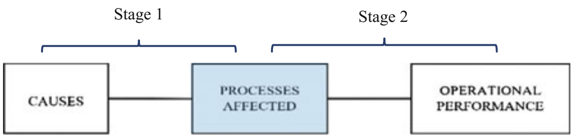
3 Links Between Levels: A Theoretical Model for the Analysis of Hidden Costs

Once defined the causes of hidden costs, the processes affected and the impacts in the operational performance, we need to identify the links and connections between them.

This will be done by placing the processes as the central element in the model, relating them to the causes that generate problems (first stage), and to the impacts on operational performance (second stage). Figure 1 shows the general outline of the theoretical model. The idea of this model is that a hidden cost can be explained as a sum of factors (causes) that provoke certain unexpected troubles in a process which give rise to performance problems that are finally quantified as a cost.

The connections have been established through the analysis of the processes in offshoring experiences. Some of the links are based on literature references while

Fig. 1 Scheme of the theoretical model



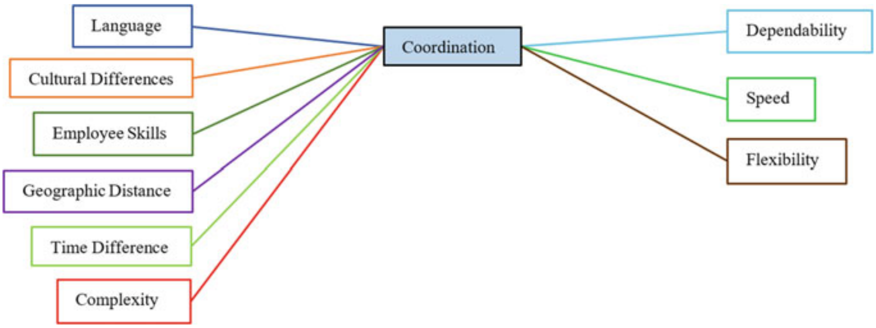


Fig. 2 Causes of coordination problems and their impact on performance

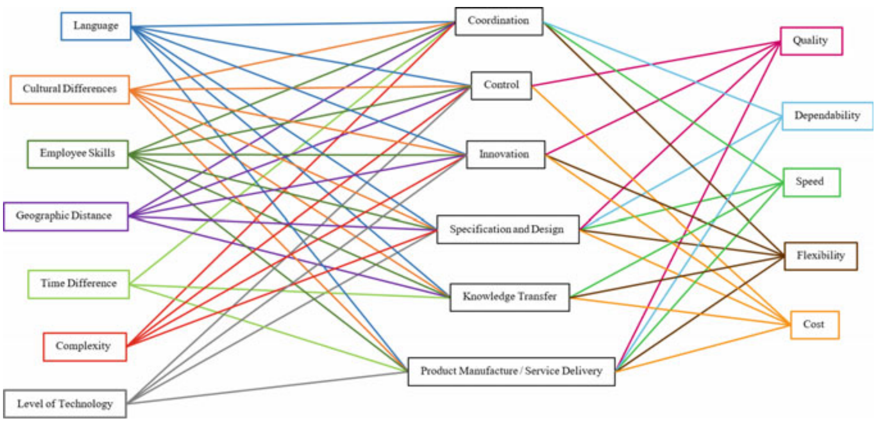


Fig. 3 Complete theoretical model. Causes–Processes–Impact on performance

others are the result of the analysis of the causes, processes and impact, being thus, a new contribution. In this sense, it is important to stand that the relationships defined are those considered most relevant and frequent, not meaning that new relationships cannot be included if observed in other experiences.

In Fig. 2 we can observe the result of the analysis around the process of coordination. The unexpected issues faced in the process of coordination are caused by all the causes discussed except from the level of technology, meaning that hidden costs related to problems in this process can be explained in terms of language issues, cultural differences, distance, etc. At the same time, problems in coordination result in dependability, speed or flexibility drawbacks.

When the same analysis is made for all the six processes discussed, we obtain the complete theoretical model, which aims to contemplate every possible hidden cost in internationalization-related processes (Fig. 3).

Table 4 Case studies on the energy sector Villa (2016)

Company	SENER Grupo de Ingeniería S.A.	Técnicas Reunidas S.A.	Acciona S.A.
Location	Buenos Aires (Argentina)	Minatitlan (Mexico)	Bookport (South Africa)
Start and end dates	2006–2009	2014–2017	2013–2016
Type of project	Combined Cycle Power Plant 2 × 2 × 1 (800 MW)	Refinery	Thermosolar Power Plant (50 MW)
Approximate budget	US$820,000,000	US$880,000,000	US$330,000,000

4 Case Studies on the Energy Sector. Application of the Model

As exhibited before, three case studies of engineering projects are analysed, in order to verify the validity of the model in these domain of internationalization. These consist on turnkey projects carried out by three spanish companies in international locations. The main data from the projects is presented in Table 4.

The information needed for the analysis of the case studies has been obtained by means of interviews to a position of responsibility of each project. To structure the interviews, a research protocol was developed. The interviewee identified in each case the main extra costs faced during the development of the project, explaining the unexpected problems that induced these costs based on the processes affected. Data analysis was carried out involving coding, narration and interpretation (Yin 2003). In this way, these problems have been analysed backwards (causes of those problems) and forward (impact in the final performance), thus applying the theoretical model already presented.

The SENER case will be presented in greater detail in order to facilitate the understanding of the model and its application. After that, the results obtained from the analysis of the other two projects will be exposed to get an overview of the application of the model and of the hidden costs in the energy sector,

SENER Grupo de Ingeniería S.A. is a Spanish business group that develops engineering projects in various areas, having presence in a great number of countries from different continents, being thus relevant in terms of international experience.[1] As exposed in Table 4, the project developed by SENER and analysed around the study of hidden costs consists on a combined cycle power plant built in Buenos Aires (Argentina). Throughout the development of the project, there were a number of unexpected problems related to the international location of the plant. These are presented in Table 5, exposing their causes, the processes affected and

[1]The information about SENER Grupo de Ingeniería S.A. has been obtained from its website: www.engineeringandconstruction.sener.

Table 5 Hidden costs in the development of the combined cycle power plant by SENER

Problem	Causes	*Process affected*	Impact
The Specification and Design team of Buenos Aires were not used to turnkey-type projects. Lack of coordination with the headquarters' in Bilbao (Spain)	Cultural differences Employee skills	*Coordination*	Reliability Speed
Lack of certain supplies in Argentina. Thus, SENER had to import them from the US, from a specialized manufacturer	Level of technology	*Specification and design*	Reliability Speed Cost
The need of an extra control point after US manufacturer of the supplies	Level of technology Complexity	*Control*	Cost
Structural problems in the transport of pieces. Impossibility of bridges to support certain loads	Level of technology	*Product manufacture* *Service delivery*	Speed Cost
Greater need for pile foundation and absence of sufficient qualified companies in Argentina. SENER had to hire a Spanish firm to do so	Level of technology	*Product manufacture* *Service delivery*	Reliability Cost

their impact on performance. Thus, the extra expenses incurred in the project can be dissected according to the model obtained from the analysis of the literature.

The model has been applied satisfactorily to the other two cases, validating it as an adequate model for the study of hidden costs in international engineering projects. It has also been observed that the number of unexpected problems faced by Técnicas Reunidas during the development of the refinery is significantly lower than in the other two cases. As discussed by the interviewee, the firm's procedures for the building of these plants are very well defined, precluding the appearance of hidden costs. It is noted the effect of studying these costs both in offshoring and in these projects as a key mechanism to predict and avoid them in future experiences.

The combination of the results from the cases leads us to the scheme presented in Fig. 4. The boxes and the lines connecting the levels have greater thickness based on the times each level or connection has appeared in the cases studied. This way, we obtain conclusions regarding hidden costs in this sector, as it can be deduced, for example, the important incidence of certain causes, the strong relationship between problems in the plant building process and the level of technology, or the huge impact these problems have directly on cost performance.

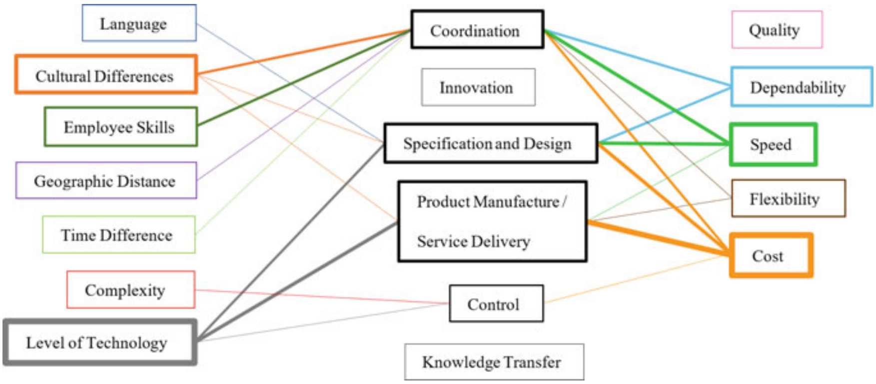


Fig. 4 Application of the model to the cases

5 Conclusions

Thanks to the literature review it has been possible to obtain a model that facilitates the analysis of the hidden costs through its division into three levels. The main conclusion is thus the theoretical model itself. Of course, the model is sensitive to updates when analyzing new experiences, and new relationships should be included when noted as relevant. The prediction of the hidden costs in future international engineering projects is facilitated by focusing on susceptible processes, evaluating the factors that can cause problems in those processes and ultimately trying to anticipate the possible impacts in performance. The application of this model to the cases allows to draw patterns associated to the type of technology or the location facilitating the future prediction of hidden costs through the construction of a risk analysis model. This can be verified with the conclusions obtained with respect to the energy sector, and the usefulness of these conclusions can be deduced from what was commented on the case of Técnicas Reunidas.

In short, it has been exposed a model that serves as a framework for the study of hidden costs in engineering projects, having validated it through its application to three real cases from the energy sector.

References

Acemoglu, D., & Dell, M. (2010). Productivity differences between and within countries. *American Economic Journal: Macroeconomics, 2*(1), 169–188.

Ceci, F., & Prencipe, A. (2013). Does distance hinder coordination? Identifying and bridging boundaries of offshored work. *Journal of International Management, 19*(4), 324–332.

Deutsch, S. (2014). Studying the hidden costs of offshoring—the effect of psychic distance. *Copenhagen Business School, Applied Economics and Finance (AEF)* (*Master thesis*).

Gray, J., Roth, A., & Leiblein, M. (2011). Quality risk in offshore manufacturing: Evidence from the pharmaceutical industry. *Journal of Operations Management, 29*(7–8), 737–752.

Jensen, P., Larsen, M., & Pedersen, T. (2013). The organizational design of offshoring: Taking stock and moving forward. *Journal of International Management, 19*(4), 315–323.

Larsen, M., Manning, S., & Pedersen, T. (2012). Uncovering the hidden costs of offshoring: The interplay of complexity, organizational design, and experience. *Strategic Management Journal, 34*(5), 533–552.

Lewin, A., Massini, S., & Peeters, C. (2009). Why are companies offshoring innovation? The emerging global race for talent. *Journal of International Business Studies, 40*(6), 901–925.

Matloff, N. (2005). Offshoring: What can go wrong? *IT Professional, 7*(4), 39–45.

Neely, A. (2011). *Business performance measurement* (2nd ed.). Cambridge: Cambridge University Press.

Slack, N., Chambers, S., & Johnston, R. (2010). *Operations management* (6th ed., pp. 32–59). Harlow, England: Financial Times Prentice Hall, Pearson.

Stringfellow, A., Teagarden, M. B., & Nie, W. (2008). Invisible costs in offshoring services work. *Journal of Operations Management, 26*(2), 164–179.

Villa, P. (2016). Costes ocultos en procesos de deslocalización. Aplicación al sector energético. Escuela Técnica Superior de Ingenieros Industriales. Universidad Politécnica de Madrid.

Yin, R. K. (2003). *Case study research: Design and methods* (3rd ed.). SAGE Publications.

The Portfolio Management and Influence in Projects of Decisions

R. Baptestone and R. Rabechini

Abstract One of the main objectives of portfolio management is related to the strategic alignment of the projects with the organizational strategy, through decision making. From this premise the present article aims to demonstrate how the portfolio management influences the decision making process in the projects of a financial organization. To achieve this goal, the project portfolio management processes and their relationships with decision making were studied. The methodological option chosen was a unique case study. The collected data were treated and analysed using the technique of qualitative data analysis through five phases of analysis and their interpretations. The results confirmed that use of the project identification process in portfolio management influence decision-making and as consequence, adding value to the business. It was also possible to demonstrate moderately that the use of criteria for project selection influences the consequences of decision making, to assist in the strategic management of the organization.

Keywords Portfolio management · Project management and decision making

1 Introduction

Portfolio management is a dynamic decision-making process in which projects are constantly updated and revised. The concept of portfolio had its origins in the 1950s in the financial sector, but it was from the 1990s that the theme became more explored. The concept of the portfolio is addressed in different sectors: financial, products, among others. Portfolio can be addressed too with projects. It covers a

R. Baptestone (✉) · R. Rabechini
Dpto. Master's Program in Business Administration Project Management, Universidade Nove de Julho, São Paulo, SP, Brazil
e-mail: rolney.caio@gmail.com

R. Rabechini
e-mail: roquejr@usp.br

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series of decision-making, including periodic portfolio reviews of all projects, to define the allocation of strategic resources.

For Cooper et al. (1997), it is necessary to integrate harmonically the decision making in order to minimize conflicts between decisions and reviews throughout the portfolio management chain. In addition, portfolio management models use a lot of information that can overwhelm the executives of organizations and therefore can't use them properly. And this leads to the need to clearly define the criteria that will be used for decision-making.

The process of management and the transparency of the information about the projects of the portfolio form the basis for a good decision making and facilitate the prioritization of the projects aligned with the company strategy (Cooper et al. 2001; Kester et al. 2011). However, the lack of management process and lack of project information have been highlighted as a central barrier to the success of the project portfolio (Cooper et al. 2001).

One of the aspects revealed in understanding what constitutes effective portfolio management and decision-making is that little attention has been given to developing a portfolio management support system that could assist in the decision-making process under uncertainties (Oh et al. 2012). This study is justified by the fact that there have been regular calls in the literature for the development of portfolio management processes aimed at effective decision making (Cooper et al. 1999, 2004a, b, c; Hauser et al. 2006), since the academic focus with emphasis on portfolio management has essentially been on methods for selection (Englund and Graham 1999; Cooper et al. 2001; Blau et al. 2004).

In keeping with this brief description, this research has a main objective to demonstrate how the portfolio management influences the decision-making process in the projects of a financial organization, and according to Dean and Sharfman (1996), effective decisions should be based on organizational objectives and complete and accurate information about the relationship between choices and results. In order to understand the relationship between portfolio management and decision making, a research question was formulated that guided the realization of this article: How does portfolio management influence decision making within the projects of a financial organization?

The objective of this research unfolds in the following objectives: (a) understand how portfolio management variables contribute to the decision-making process in the organization; (b) present the set of variables that characterize the decision making; and (c) identify what in the portfolio management helps directly in the decision making.

2 Theoretical Reference

Portfolio management had its origins in the 1950s in the financial sector, but it was from the 1990s that the theme became more explored. As a foundation for the theoretical review, there are two key themes that will drive all research, on the one hand, portfolio management based on the seven stages that make up a portfolio, according to de Castro and de Carvalho (2010): alignment with strategic priorities, definition Project selection, project selection and prioritization, resource allocation and portfolio control, as well as the three levels that control the portfolio: strategic, tactical and operational. On the other hand, there will be decision making based on rationality, political behaviour and intuition, as suggested by Elbanna (2006), and effective decision making, according to Dean and Sharfman (1996).

The connection of these two disciplines, portfolio management and decision making, is due to the fact that the decision process is present in all phases of portfolio management. But Danesh et al. (2015) argue that in order to effectively execute portfolio management, managers in organizations should review their strategies and prioritize strategic plan goals from effective decisions. They need to map their projects, and justify their priority against all the other projects in the organization.

According to Closs et al. (2008), decisions in the portfolio are complicated and often require a lot of information for decision making, many of them intangible or involving some level of risk, in an area that may include contradictory objectives, containing both quantitative and qualitative factors. The accuracy in estimating relevant data through decision-making practice is essential for portfolio success. It is desirable that such practices have the ability to report possible uncertainties, inaccuracies or lack of information. They need to clearly inform the different qualitative data and what are the quantitative variables for decision making in the portfolio management process.

After analysing the themes that guided this work, we will evaluate the variables, described in Table 1 that will help in the construction of the specific objectives to reach the objective of this research, which is to understand how the portfolio management can influence the process of making Decisions in an organization's projects.

Table 1 shows the search variables associated with authors and themes, Portfolio Management (PMP) and Decision Making (DM). Each variable received a number, its relation to the corresponding theme and the name of the variable, which are directly linked to the main contributions of the authors associated with each variable. These variables will be used in the conceptual model of the research in the next chapter.

The variables related to the themes will be the basis for the generation of the conceptual model and the propositions of this research, as well as the methodology adopted to verify the relationship between portfolio management and decision making.

The model is composed of two theoretical axes, portfolio management and decision-making. It was evaluated who makes the decision during the decision-making process in relation to portfolio projects. Through the conceptual model proposed in Fig. 1, it was possible to verify, through the propositions, if the main objective of this research, to understand if the portfolio management can influence the decision making process in the projects of an organization.

Table 1 Theoretical review

Theme	Authors	Main contributions	Variable
Portfolio management (PMP)	Mikkola (2001)	He argued about the importance of portfolio management as a strategic tool for the company's positioning in terms of growth and sustainability of results	V1-PMP—Process
	Teller et al. (2012)	It examines that project portfolio management can only operate if project information is available through formal procedures and rules to improve the availability of information, thus facilitating the comparison between different projects	
	Cooper et al. (2001a)	Focused portfolio management for product development through a portfolio decision process that encompasses a range of in-company decision-making processes, including periodic revisions of the project portfolio	
	Heising (2012)	It points out that only effective project management is no longer enough. And that Portfolio management becomes increasingly important to achieve success and competitive advantage in the long run	
	Cooper et al. (2002)	They identified that companies with best portfolio management practices use the "Stage-Gates" model (decision-making gates in the portfolio management process)	V2-PMP—Criteria for selecting projects
	Coldrick et al. (2005)	They identified, as a benefit of the use of the selection model, the formal decision structure and communication of information about projects	
	Wang and Hwang (2007)	It contributed to the selection of project portfolios within a scenario of lack or insufficiency of reliable information for risk minimization	
	Danesh et al. (2015)	Discusses the options for improving decision making in organizational portfolio management results using hierarchy analysis processes (AHP)	
Decision making (DM)	Dean and Sharfman (1996)	The process of obtaining information relevant to the decision and its dependencies. And the analysis of this information to make the choice	V1-DM—Goal
	Elbanna (2006)	How are strategic decisions made?	
	Kester et al. (2011)	Understand how companies manage the portfolio for new product development and what challenges companies face in making	

(continued)

Table 1 (continued)

Theme	Authors	Main contributions	Variable
		decisions during the project selection process	
	Pettigrew (1973)	Explore issues of power and conflict in organizational life	V2-DM—Consequences
	Pfeffer (1981)	Study the influence on the results of the decisions, so that the interests themselves are served, through political techniques	

Source Prepared by Author

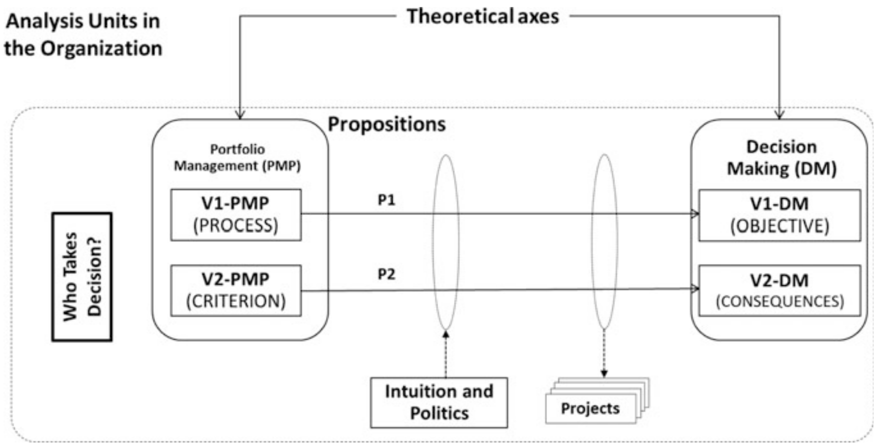

Fig. 1 Conceptual model of the case study

In the propositions, Table 2, the portfolio management processes will be evaluated on the projects and how these processes help decision making at all levels within the company.

3 Methodology

This research used the single case study method, through the interpretative paradigm of research, directed to twelve professionals (Table 3) of a medium financial organization who had more than a year contact with portfolio management and decision making.

The methodology used for the analysis and interpretation of the data obtained in this case study was the analysis of qualitative data through five phases of analysis

Table 2 Research Proposition

Propositions	Authors: Portfolio management	Authors: Decision making
P1: The use of the process of identifying projects influences the objective of decision making	Copper et al. (2001) and Heising (2012)	Pettigrew (1973), Mintzberg et al. (1976), Fredrickson (1984), Pfeffer (1981), Eisenhardt and Bourgeois (1988)—Based on Dean and Sharfman (1996), Clemen and Reilly (1996), Russo and Schoemaker (2002), Bazerman and Moore (2009) and Kester et al. (2011)
P2: The use of criteria for project selection influences the consequences of decision making	Copper et al. (2002), Coldrick et al. (2005), Wang and Hwang (2007) and Danesh et al. (2015)	Clement and Reillyn (1996), Russo and Schoemaker (2002), Bazerman and Moore (2009) and Kester et al. (2011)

Source Prepared by Author

Table 3 Professionals who participated in the case study

Job role	Occupation area
Director	CFO—Chief Financial Officer
Manager	PMO Manager
Manager	Product manager
Manager	IT Manager
Manager	Accounting and Conciliation with Partners
Coordinator	PMO Coordinator
Coordinator	IT Coordinator Siebel ("Core" of the Business)
Specialist	The only project manager with PMI certification
Specialist	Business area, responsible for the specifications of the commercial areas and products
Specialist	PMO Specialist
Specialist	New business
Senior analyst	Leading analyst of IT solutions Siebel ("Core" of the Business)

Source Prepared by Author

and their interpretations, based on Yin (2016). Initially, all the interview material was transcribed, later analysed on a case-by-case basis with the questionnaires. The entire content of the interviews was organized into initial categories (Initial Code—Level 1) established with the aid of software (Excel) for analyses and textual statistics. Subsequently it was carried out and interpreted in a consolidated way together with the bibliographical review, and the results obtained were organized and described in new categories (Category Code—Level 2) grouped by analogy.

4 Analysis and Interpretation of Results

Through the analyses of the collected data, it was possible to evaluate the relationship between project portfolio management and decision-making, verifying its existence and relevance, through the following topics. The main goal to be achieved during decision-making is to focus on the strategic objective of the organization. It is necessary to know the project estimates to add value during decision-making.

The importance of evaluating the impacts of a project on the business was detected, with the help of portfolio management, in order to handle the most important information and to support the decision-making process. It was verified in this research that the profitability and return on investment, captured in the process of portfolio management, are the most important information for a decision-making. And, that the most important information for choosing a specific project is the return on investment. Taking into account that information is the basis for decision-making in 75.83% of cases, and that intuition can also be used in 24.71% of cases, when the decision maker does not hold all the information.

To 91.67% of respondents is that the opinion of the most powerful prevails during the decision-making process. In relation to the managers' attempt to influence the results, in the portfolio management process, 50% of respondents believe that there are no attempts to influence the results of decision processes, to serve their own interests, aiming at improvement and continuity of business, of adding value. While the other 50% believe that there are attempts to influence the outcomes of decision processes, to serve their own interests, they do so through the strategic planning process.

The strengths of portfolio management to assist in decision-making are related to strategic planning and efficiency. While the improvements pointed out, they are related to the maturity of strategic planning, to reach the strategic objectives of the organization, thinking as a company and not in an individualized sector. It was verified that the most used method in the company for the decision-making was the financial method, using financial indices (example, net present value and payback), in the opinion of 55% of the interviewees. The pros of the method most used in the company for decision-making, is the return on investment with 50% of the opinions. While the cons of the method most used in the company for decision-making, is to "not contribute to improvement and business continuity". It can leave important projects aside, for example: structuring projects, projects that aim at improving the perception of customers, among others.

It was detected that the use of criteria directly assists decision making, through the targeting of well-defined strategic objectives. In this research, we noticed an increase in the criteria already used in the literature to verify other important items within the organization that should also be taken into account: mitigation of operational risks, business intelligence, business diversification, audit points and quality. According the interviews, portfolio management influences decision making because it makes clear the objectives of each project, in a structured way, one in comparison to the other and that at an executive level makes the decision much easier With this, we verified that the positive relationship between the two constructs of this research demonstrates the relevance of the research, bringing to managers the importance of portfolio management to the organizations strategy, precisely by assisting them in decision making, in order to corroborate with Siqueira and Crispim (2014), who believe that one of the greatest challenges for organizations is to develop and improve the ability to compose a project portfolio that is aligned with the business model and that contributes to achieving the results and benefits expected by the organization.

5 Conclusions

According to the results it was possible to answer the research question about how does portfolio management influence decision-making within the projects of a financial organization. Such a relationship of influence was possible by accepting proposition 1, the use of the process of identifying projects influences the objective of decision making, with the capacity of portfolio management to influence decision making, adding value to the business, being aligned with the organization's strategy, generating financial returns and positive impacts on the business. It was also possible to identify strategic management, financial return and the capacity to add value as criteria of moderate relevance in the decision making process, accepting proposition 2, the use of criteria for project selection influences the consequences of decision.

Regarding the practical implications, it was observed among the interviewees that the decision making, with the help of portfolio management, makes the decision making process more robust, since the decision maker can see the whole in detriment of only one project. Therefore, the importance of looking at the whole to make the decision, to the detriment of the evaluation of only one project, in an isolated way for a decision making that can impact the other projects of the company. According to the interviewees, the strengths of portfolio management to aid decision making are related to strategic planning and efficiency. Emphasizing that the results of this research can not be treated in a generalized way, due to the methodological procedure adopted. However, the results obtained may be considerations, suggestions and options based on the experiences of a particular group that can be discussed or adopted by other organizations and professionals in different areas, provided they have worked with the portfolio management process.

References

Bazerman, M. H., & Moore, D. (2009). *Judgment in managerial decision making* (7th ed.). Local: Wiley.

Blau, G. E., Pekny, J. F., Varma, V. A., & Bunch, P. R. (2004). Managing a portfolio of interdependent new product candidates in the pharmaceutical industry. *Journal of Product Innovation Management, 21*(4), 227–245.

Clemen, R. T., & Reilly, T. (1996). *Making hard decisions. An introduction to decision Analysis* (2nd ed.). Belmont CA: Duxbury Press.

Closs, D. J., Jacobs, M. A., Swink, M., & Webb, G. S. (2008). Toward a theory of competencies for the management of product complexity: Six case studies. *Journal of Operations Management, 26,* 590–610.

Coldrick, S., Longhurst, P., Ivey, P., & Hannis, J. (2005). An R&D options selection model for investment decisions. *Technovation, 25*(3), 185–193.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (1997). Portfolio management in new product development: lessons from the leaders—II. *Research Technology Management, 40*(5), 43–52.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (1999). New product portfolio management: Practices and performance. *Journal of Product Innovation Management, 16*(4), 333–351.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (2001). Portfolio management for new product development: Results of an industry practices study. *R&D Management, 31*(4), 361–380.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (2002). Optimizing the stage-gate process: What best-practice companies do-II? *Research Technology Management, 45*(5), 21–28.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (2004a). Benchmarking best NPD practices I. *Research-Technology Management, 47,* 31–43.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (2004b). Benchmarking best NPD practices II. *Research-Technology Management, 47,* 50–59.

Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (2004c). Benchmarking best NPD practices III. *Research-Technology Management, 47,* 43–55.

Danesh, D., Ryan, M. J., & Abbasi, A. (2015). Using analytic hierarchy process as a decision-making tool in project portfolio management. *9*(12), 3988–3998.

de Castro, H. G., & de Carvalho, M. M. (2010). Gerenciamento do portfólio de projetos (PPM): estudos de caso. *Produção, 20*(3), 303–321.

Dean, J., Jr., & Sharfman, M. (1996). Does decision process matter? A study of strategic decision making effectiveness. *The Academy of Management Journal, 39*(2), 368–396.

Eisenhardt, K. M., & Bourgeois, L. J. (1988). Politics of strategic decision making in high-velocity environments: Towards a midrange theory. *Academy of Management Journal, 31,* 737–770.

Elbanna, S. (2006). Strategic decision making: Process perspectives. *International Journal of Management Reviews, 8*(1), 1–20.

Englund, R. L., & Graham, R. J. (1999). From experience: Linking projects to strategy. *Journal of Product Innovation Management, 16,* 52–64.

Fredrickson, J. W. (1984). The comprehensiveness of strategic decision processes: Extension, observations, future directions. *Academy of Management Journal, 27*(3), 445–466.

Hauser, J., Tellis, G. J., & Griffin, A. (2006). Research on innovation: A review and agenda for Marketing Science. *Marketing Science, 25,* 687–717.

Heising, W. (2012). The integration of ideation and project portfolio management—A key factor for sustainable success. *International Journal of Project Management, 30*(5), 582–595.

Kester, L., Griffin, A., Hultink, E. J., & Lauche, K. (2011). Exploring portfolio decision-making processes. *Journal of Product Innovation Management, 28*(5), 641–661.

Mikkola, J. H. (2001). Portfolio management of R&D projects: Implications for innovation management. *Technovation, 21*(7), 423–435.

Mintzberg, H., Raisinghani, D., & Theoret, A. (1976). The structure of 'unstructured' decision processes. *Administrative Science Quarterly, 21,* 246–275.

Oh, J., Yang, J., & Lee, S. (2012). Managing uncertainty to improve decision-making in NPD portfolio management with a fuzzy expert system. *Expert Systems with Applications, 39*(10), 9868–9885.

Pettigrew, A. M. (1973). *The politics of organizational decision making*. London: Tavistock.

Pfeffer, J. (1981). *Power in organizations*. Marshfield, MA: Pitman.

Russo, J. E., & Schoemaker, P. J. H. (2002). Decisões vencedoras: como tomar a melhor decisão, como acertar na primeira tentativa. Trad. Hugo Melo. Rio de Janeiro: Campus.

Siqueira, L. D., & Crispim, S. F. (2014). Alinhamento dos projetos de TI aos modelos de negócio das organizações. *Gestão & Produção, 21*(3), 621–634.

Teller, J., Unger, B. N., Kock, A., & Gemünden, H. G. (2012). Formalization of project portfolio management: The moderating role of project portfolio complexity. *International Journal of Project Management, 30*(5), 596–607.

Wang, J. T., & Hwang, W. I. (2007). A fuzzy set approach for portfolio selection using a real options valuations model. *Omega-International Journal of Management Science, 35*(3), 247–257.

Yin, R. K. (2016). Pesquisa qualitativa do início ao fim. Tradução: Daniel Bueno. Porto Alegre. Ed. Penso.

USA, Europe and Pharmerging Countries: A Panorama of Pharmaceutical Innovation

A. C. S. Akkari, I. P. Munhoz and N. M. B. F. Santos

Abstract China and Brazil appear as major emerging pharmaceutical markets and the literature suggests that the sustainable development of the pharma industry will depend on the pharmerging countries. The mapping of this sector in the technological and industrial scope was the objective of this work, considering international database patent analysis (World Intellectual Property Organization and Derwent) and the implementation in MATLAB® of an algorithm for scenario prediction. It was found that most pharmaceutical patents in the world are filed in the USA (23%) and Europe (29%), notably the innovation indices of Roche (1032 patents) and Novartis (671 patents). However, it was observed an estimated increase of more than 25% in the number of Brazilian and Chinese pharmaceutical patents, suggesting the dissemination of technological and scientific knowledge and an increase in competitiveness in this strategic segment.

Keywords Innovation · Pharmerging country · Patent · Technology mapping Pharmaceutical industry

A. C. S. Akkari (✉)
Science and Technology Center, Mackenzie Presbiterian University,
Av. Brasil, Campinas 1220, Brazil
e-mail: alessandra.akkari@mackenzie.br

I. P. Munhoz
Federal Institute of São Paulo, Avenida Mutinga, 951, São Paulo, Brazil
e-mail: igor.munhoz@ifsp.edu.br

N. M. B. F. Santos
Department of Administration, Pontifical Catholic University of
São Paulo, Rua Monte Alegre, 984, São Paulo, Brazil
e-mail: admneusa@pucsp.br

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1 Introduction

Innovation is the driving force behind progress in the pharmaceutical industry since pursuing protections for new products and processes is a stimulating factor for higher investments in R&D, which involves costly activities that have a low success rate and require a long time (average success rate of 4.9% from first toxicity dose to market approval). As such, obtaining patents ensures temporary exclusive marketing rights for drugs, yielding extraordinary profits and significant competitive advantages to innovative companies (Bunnage 2011; Schuhmacher et al. 2016).

Traditionally, USA and European Industry have spearheaded the pharmaceutical segment, because they have been favored by a smoother regulatory environment and by lower price control since the 1940s (Fernald et al. 2017). However, the relevance of emerging pharmaceutical markets, also known as pharmerging countries, is growing and will certainly boost the increase in drug sales mainly due to aging population (Evaluate Pharma 2016).

Pharmemerging countries are defined according to IMS Health on the basis of indicators and macroeconomic forecasts for the pharmaceutical segment. The IMS (2016) has demonstrated the high potential of pharmaceutical markets in China and Brasil, suggesting that the sustainable development of the pharmaceutical industry will depend of pharmemerging countries. Thus, the CAGR is expected to reach the indices of 15–18 and 11–14 for China and Brazil, respectively, considering the period 2017–2021. Otherwise, growth of only 2%, at the same indicator and for the same period, is expected in the 8 most mature markets (e.g. USA).

Therefore, the technological and industrial mapping was the objective of this work, through the patent analysis by country and technology, highlighting the comparison of the innovation indices of pharmerging countries (China and Brazil) with the innovation indices of Europe and USA.

2 Pharmaceutical Innovation

Not every new drug is innovative with the same intensity and this fact has stimulated the debate on innovation within the pharmaceutical segment. As an example, there is an increase in the number of launches of *me-too* drugs, which refer to products with the same therapeutic activity as that already existing in the market, offering no significant additional benefit in terms of effectiveness and/or safety (Aronson 2008).

Aronson et al. (2012), in a review published in *Nature—Drug Discovery Section*, define the term rewardable innovation for the pharmaceutical industry as a rewardable innovation, suggesting a way to assess to what extent the inventors of a new therapeutic compound should be rewarded for innovation. Thus, the key requirements to be met for a pharmaceutical innovation are novelty (new product or new application); utility (the risk-benefit balance must be considered); and revolutionary (disruptive) or incremental innovation.

The same group of researchers find it difficult to reward incremental innovation as they believe in pharmaceutical innovation to exceed a small improvement resulting from a chain of improvements. Besides that rewarding incremental innovation may discourage revolutionary innovation. In addition, the need for engagement and interaction between the different actors involved in the innovation process, such as patients, pharmaceutical companies, health systems and government, is highlighted (Aronson et al. 2012).

The idea of rewardable innovation has been applied by the UK's Office of Fair Trading (OFT), which understands that as long as there is no definition of innovation for medicines, innovation should be rewarded when new drugs significantly improve the therapeutic standards conferred by existing treatments (OFT 2007).

3 R&D and Pharma Patent Protection

Thousands of substances are developed in the laboratory, but only a few of these will eventually result in an approved drug, involving years of development and testing. Although new technologies have been developed in order to reduce the timelines and to increase success rates in drug discovery, R&D efficiency, obtained by analyzing the number of new drugs (new molecular entities—NME) launched in the market by pharmaceutical industries and their R&D spending, has declined (Bunnage 2011; Scannell et al. 2012; Schuhmacher et al. 2016).

Currently, there is an effort under way from the pharmaceutical companies to optimize the returns on R&D activities, applying considerable changes in order to increase revenue, optimize costs and reduce R&D cycle times, mainly through the formation of strategic alliances.

When considering R&D activities in the pharmaceutical industry, it is worth mentioning that patent protection is an integral part of the process of developing and launching a new drug in the market. Therefore, the pharma innovation process includes both R&D activities and patent protection in order to guarantee the maintenance of high investments. Thus, certainly the absence of a consolidated intellectual property (IP) system can affect the pharmaceutical sector more intensely than it would affect other sectors of the economy (Scherer and Ross 1990).

Patent indicators are parameters for measuring the innovative activity of a country (OECD 2007) and the monitoring of patent databases has therefore become a decision making aid to define the direction of research and investments as well as to make comparisons possible between the innovation rate of different regions and countries, enabling the identification of trends and bottlenecks in the sector (Masiakowski and Wang 2013).

4 Methodological Approach to the Forecasting and Analysis of Pharmaceutical Patents

This is an exploratory study, which integrates the collection and analysis of secondary data and a bibliographical research.

Thus, the study was based on the collection and rating of information extracted from WIPO (World Intellectual Property Organization), a United Nations agency that presents statistical information on patent applications worldwide. The data collected are general; describe the patent applications in each country analyzed by field of technology and the measure of the number of protections granted for the selected field in a certain time interval. The analysis occurred from 1996 (when the Industrial Property Law was approved in Brazil) until the last record date. Also, the Derwent Innovations Index was consulted—a search tool provided by Thomson Reuters that provides information about industrial property.

After the data collection, the Least Squares Method was used to approximate the behavior of the variables for a known polynomial function, using data from five years ago. In this step, an algorithm was implemented in MATLAB®. It should be pointed out that, among several approaches, the use of the least squares method was chosen using the Polynomial Approximation for Discrete Cases, which allows an approximation for a function F(x) given by n + 1 pairs of points (Bengisu and Nekhili 2006; Chen et al. 2011).

5 WIPO Pharmaceutical Patent—Country of Origin

Firstly, the pharmaceutical industry was evaluated by the number of patents granted by country of origin according to WIPO (Fig. 1). The USA and the Europe in the world ranking of pharmaceutical patents are highlighted, with 126,747 USA protections (23%) and 162,721 European protections (29%), with a large contribution by Germany, France and the United Kingdom. Also noteworthy is the significant collaboration of China (7.09%, 39.460 patents) and Japan (6.03%, 33.539 patents) for the pharmaceutical sector, pointing out that the innovative activity in China has already surpassed the Japanese index, which until then was considered the global leader in the sector.

Brazil, on the other hand, has a very low ranking in the world scenario (37°), since in the sixteen years analyzed, the country had only 321 pharma patents, corresponding to 0.06% of total protection. The Brazilian index is below that observed in India (0.67%) and in Cuba (0.11%), similar to that in South Africa.

The data collected corroborate reports in the literature that affirm that the absence of technological innovation in the Brazilian drug industry is due to the low stimulus to the most intensive activities in science and technology (like R&D) in the Brazilian producer sector. The pharmaceutical value chain, whose overall objective is to define, validate, discover, produce and sell new drugs, is basically composed

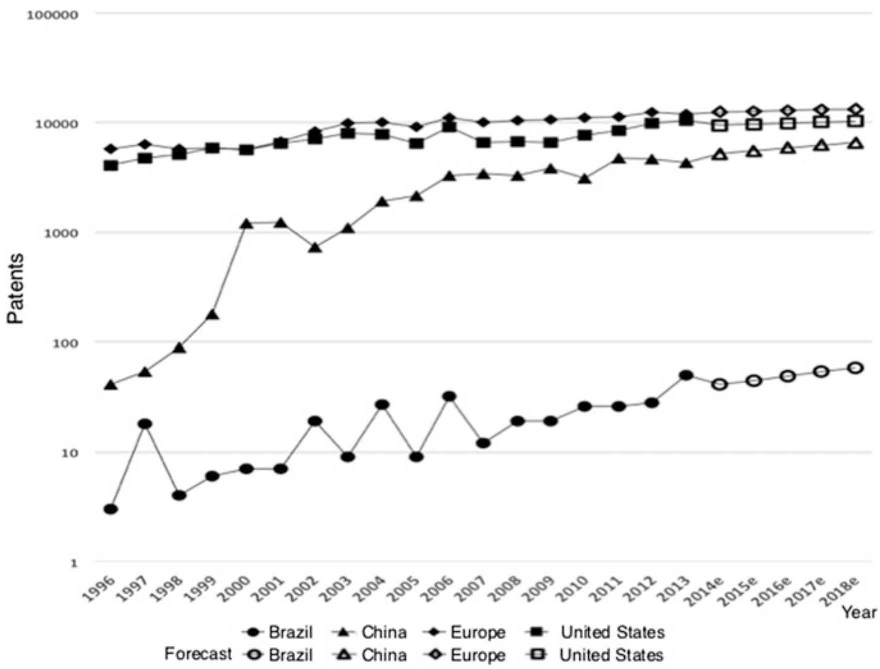

Fig. 1 Pharmaceutical patents granted in different regions and a forecast of 5 years. Developed by the authors based on WIPO (2016)

of four technological stages: R&D of new drugs; drug industrial production; production of pharmaceutical specialties; and marketing and sale (Frenkel 2002; Yousefi and Alibabaei 2015). Unlike in Brazil, historically the European pharmaceutical industries (such as Roche and Novartis) and the USA (like Pfizer) invest heavily in R&D, being companies with technological and scientific competencies that stimulate and promote innovation in the sector industrial (Schuhmacher et al. 2016).

When comparing pharmerging countries, it is noticed that China has been giving rise to an increasing number of patents, demonstrating an engagement in the exploration of its pharma market. In fact, the Chinese government confirmed the pharmaceutical sector as a priority in science and technology scope in the country's medium-term plan (Gassman and Zedtwitz 1999; Wang et al. 2009).

The expected scenario (Table 1) converged to a considerable increase in the number of Brazilian protections. A decline occurred in 2014, followed by a recovery to reach 568 patents by 2018, representing a relative up of 41%. In the same timeframe, China is expected to reach approximately 69 thousand pharmaceutical patents, equivalent to a relative increase of 27% between the years 2014–2018. While absolute values are considerable, a more modest growth (less than

Table 1 Prediction of pharmaceutical patents granted in different regions, between 2014 and 2018

Period		Europe	USA	China	Brazil
	2014e	12.456	9.425	5.189	41
	2015e	12.692	9.651	5.529	45
	2016e	12.908	9.872	5.872	49
	2017e	13.107	10.090	6.220	54
	2018e	13.286	10.304	6.571	58
Relative variation $VR_y = \frac{y_{x+5} - y_x}{y_x}$	2009–2013	13%	57%	12%	163%
	2014–2018	7%	9%	27%	41%

10%) is expected in the number of North American and European protections, reaching 176,089 and 227,170 pharmaceutical patents, respectively, from 1996 until the last analyzed year.

It was verified that the Chinese innovation indices are increasingly approaching the North American and European indices. Thus, it was estimated that, in less than 20 years (2036), China will reach the position of world leader in pharmaceutical sector.

6 WIPO Pharmaceutical Patent—Office

Considering the patent protection per office, the patent numbers granted by the study regions (USA, Europe, China and Brazil) were evaluated. It is noted that Europe is the most region granted pharmaceutical patents between 1996 and 2013, the equivalent of a total of 75,651 protections. In the second and third place are the US and China, with 74,761 and 65,785 patents granted, respectively.

The high interest in seeking protection in Europe and the USA can be explained by the characteristics of these regions, highlighting the high level of technology in the productive sector, consolidation of the PI system, interesting economic indicators, among other aspects. In fact, Sanyal (2004) argues that economic, technological, regulatory and political factors directly influence the attractiveness of a country to patent applications.

Public policies focused on the pharmaceutical industry, skilled labor, and expressive economist raiders explain China's leading position as the third-highest patent holder in the world.

During the analyzed period, Brazil granted 461 patents, with an increase from 2008 possibly due to the fact that this sector was recognized as strategic by the Brazilian government from 2004. These data prove that Brazil granted more patents than it requested, showing that there is an interest in the protection of new drugs in countries with pharmaceutical emerging markets.

The forecasts showed a trend in Brazil to continue being an interesting region for granting patents, with a variance of over 60% in the number of patents to be granted until 2018, reaching more than 1200 protections. For China the estimate was similar (variance of 49% from 2014 to 2018), suggesting that the interest in the pharmerging countries is increasing.

7 Industrial Mapping of Pharmaceutical Segment

In order to complement the analysis carried out on the basis of WIPO data (technology and country assessment), the Derwent database was used. It was investigated the companies of the pharmaceutical branch that had more number of pharma patents, between 1996 and 2014.

According to Fig. 2, it was observed that the pharmaceutical companies with the most patents granted in Derwent's Pharmacology and Pharmacy area are European (Hoffmann La Roche, Novartis, AstraZeneca; and Boehringer Ingelheim), totaling 2540 patents, and North American patents (Merck Sharp & Dohme, Mondobiotech Lab.; Schering; BASF and Bristol-Myers;), with a total of 1668 protections. Also noteworthy are some ICT, such as the University of California and the Beijing Guanwuzhou Biological Sciences Institute, which is Chinese.

The supremacy of North American and European industries as the largest holders of pharmaceutical patent confirming the technological mapping developed

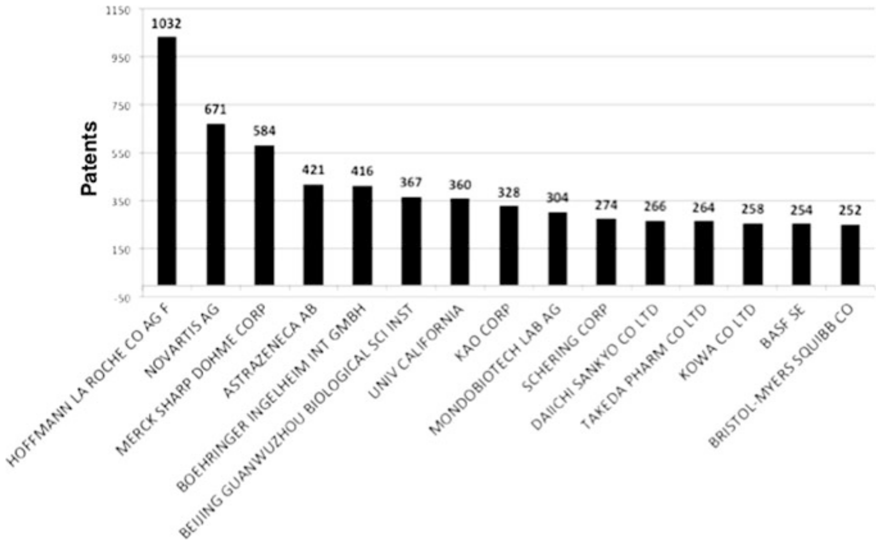

Fig. 2 Pharmaceutical companies with more patents granted in the world, between 1996 and 2014. Developed by the authors based on Derwent Innovations Index (2016)

with WIPO data. However, one Chinese institution among the world's top 15 pharmaceutical companies confirms China's growth in this segment, pointing out a path to be followed by other pharmerging countries, such as Brazil, in order to take advantage of their market opportunities.

8 Conclusion

Historical factors can be used to understand the current organization of the Brazilian pharmaceutical industry, which has established itself with deficient public policies in a highly dense and concentrated market by multinationals, highly dependent on imported pharmaceutical chemicals, low investment in R&D and focused on the production of medicines with patents expired. The data collected in WIPO reflect this scenario, so that the Brazilian pharmaceutical industry has a low innovation power, occupying a very small position worldwide. In contrast, in the current scenario, the USA and Europe have emerged as the regions with the highest number of pharmaceutical patents, indicating a high capacity for innovation.

It is worth highlighting China's growing performance in the pharmaceutical sector, suggesting a range of Chinese innovation indices to USA and European numbers. Therefore, is expected that in the coming 20 years, this pharmerging country will take the lead in pharmaceutical innovation.

In Brazilian case, it is suggested a strong governmental incentive in the pharmaceutical sector in order to enable the national industries to generate innovation, aiming to exploit the potential of the Brazilian market.

References

Aronson, J. K. (2008). Something new every day: Defining innovation and innovativeness in drug therapy. *Journal of Ambulatory Care Management*.

Aronson, J. K, Ferner, R. E., & Hughes, D. A. (2012). Defining rewardable innovation in drug therapy. *Nature Reviews Drug Discovery*.

Bengisu, M., & Nekhili, R. (2006). Forecasting emerging technologies with the aid of science and technology databases. *Technological Forecasting and Social Change*.

Bunnage, M. E. (2011). Getting pharmaceutical R&D back on target. *Nature Chemical Biology*.

Chen, Y. H., Chen, C. Y., & Lee, S. C. (2011). Technology forecasting and patent strategy of hydrogen energy and fuel cell technologies. *International Journal of Hydrogen Energy*.

Derwent Innovations Index. (2016). Thomson Reuters – Derwent World Patents Index. http://thomsonreuters.com/en/products-services/intellectual-property/patent-research-and-analysis/derwent-worldpatents-index.html.

Evaluate Pharma. (2016). *World Preview 2016, Outlook to 2022* (9th ed,). London: Evaluate Pharma's World Preview.

Fernald, K. D., Pennings, H. P., van den Bosch, J. F., Commandeur, H. R., & Claassen, E. (2017). The moderating role of absorptive capacity and the differential effects of acquisitions and alliances on Big Pharma firms' innovation performance. *PLoS One*.

Frenkel, J. (2002). Chains in which intra-firm trade predominates: Pharmaceuticals. In: Ministry of Development, Industry and Foreign Trade.

Gassman, O., & Zedtwitz, M. V. (1999). New concepts and trends in international R&D organizations. *Research Policy*.

IMS. (2016). *The global use of medicines: Outlook through 2020*. Danbury: IMS Health.

Masiakowski, P., & Wang, S. (2013). Integration of software tools in patent analysis. *World Patent Information*.

OECD. (2007). *Frascati manual: Proposed standard practice for surveys on research and experimental development* (6th ed.). Coimbra: OCDE.

OFT—OFFICE OF FAIR TRADING. (2007). *Annexe L (Evaluation of options for reform to the PPRS) the pharmaceutical price regulation scheme: An OFT market study*. London: OFT.

Sanyal, P. (2004). Intellectual property rights protection and location of R&D by multinational enterprises. *Journal of Intellectual Capital*.

Scannell, J. W., Blanckley, A., Boldon, H., & Warrington, B. (2012). Diagnosing the decline in pharmaceutical R&D efficiency. *Nature Reviews Drug Discovery*.

Scherer, F. M., & Ross, D. (1990). *Industrial market structure and economic performance* (3rd ed.). Boston: Houghton and Mifflin Company.

Schuhmacher, A., Gassmann, O., & Hinder, M. (2016). Changing R&D models in research-based pharmaceutical companies. *Journal of Translational Medicine*.

Wang, K., Hong, J., Marinova, D., & Zhu, L. (2009). Evolution and governance of the biotechnology and pharmaceutical industry of China. *Mathematics and Computers in Simulation*.

WIPO. (2016). World Intellectual Property Organization.

Yousefi, N., & Alibabaei, A. (2015). Information flow in the pharmaceutical supply chain. *Iranian Journal of Pharmaceutical Research*.

Part VI
Service Systems

Algorithm for Efficient and Sustainable Home Health Care Delivery Scheduling

N. Szander, L. Ros-McDonnell and M. V. de la Fuente

Abstract Central and Eastern European countries are lacking well-developed home care systems that would balance quality, equity and costs even more with the advancing population ageing. In this study we propose a home health care (HHC) routing and workforce scheduling algorithm, that considers a possibility of using electric bicycles instead of the currently used combination of public transport (buses) and walking. The coordination of aims, such the optimal allocation of care resources, the reduction of transport costs, sustainability and environmental awareness is tackled.

Keywords Home health care · Routing and scheduling algorithm
e-bike · Urban transport

1 Introduction

Home care is a relatively new phenomenon in Central and Eastern Europe, and in these countries the financial constraints are not supporting the improvements and the best practices of other countries—with more developed home care provision—thus, they may not be applicable in their case as such (Genet et al. 2013). In some European countries the governments gradually retreat from health and social care sectors, opening space to private entities, although the expectations of the citizens are quite clear: long-term care for the elderly (home and institutional care) should

N. Szander (✉)
Mediterranean Institute for Advanced Studies, Mednarodni prehod 6, Vrtojba, Nova Gorica, Slovenia
e-mail: norina.szander@medifais.net

L. Ros-McDonnell · M. V. de la Fuente
GIO Research Group, UPCT, Campus Muralla, C/Real 3, Cartagena 30202, Spain
e-mail: lorenzo.ros@upct.es

M. V. de la Fuente
e-mail: marivi.fuente@upct.es

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be provided by public authorities according to 90% of the respondents (ibid). During the demographic ageing, not the growing number of elderly people by itself, but the lack of informal care (declining family size, the increased participation rates of women in the labour market and the rising geographical mobility) will undoubtedly increase the demand for formal home care services (OECD 2015). In HHC the number of patients is relatively small, but they are spread over the whole area of the municipality, therefore the transport times between patients can be high and uncertain; the care is provided according to the patient needs which are in cases time-sensitive (dressing, feeding, drug/injection administering) and some of them occur at the same time but spatially separated. The process of dealing with this information includes the analysis and thorough knowledge of a series of variables such as transport types that can be used, analysis of the public routes, the location of patients, needs of patients to be visited on each route, etc. The lack of appropriate tools to support optimal routing and scheduling of HHC has led to the development of different techniques to facilitate both the calculation and implementation of these tasks, but still, many researchers point out that these complex calculations are often done manually (Eveborn et al. 2006; Trautsamwieser et al. 2011; Wirnitzer et al. 2016), which demands augmented organizational effort and potentially less efficient solutions. The aim of this paper is to present an algorithm for improving the efficiency of the home care delivery: serving the demand within the shortest time possible, with the lowest possible costs and create a proactive approach to serve the future demand that will be an inevitable result of demographic ageing. Further in this paper after the description of the objectives and methods we present the application of our algorithm on the data of the Care Centre for the Elderly (CCE) in Zalaegerszeg, Hungary and estimate the cost reduction and options for improvements in their operation.

2 Objectives and Methods

The scientific literature of HHC delivery highlights the increasing need of health and social services to be more profitable and to serve the continuously rising number of requests, therefore scholars focus on the urge of reducing costs by the means of minimizing the travel time and distance—therefore the travel cost—the waiting time, and the overtime through efficient routing (Fikar and Hirsch 2017). The modal shift of HHC delivery is a missing perspective in the scientific literature, not considered as a decision variable: whenever the transport mode is present in a study it serves to estimate certain aspects of the designed routing, such as calculation of total costs or time (Eveborn et al. 2009; Hiermann et al. 2015). As the extension of metropolitan areas was not only facilitated but also generated by motorised transport (Wegener and Fürst 1999) the obvious choice for reaching residential areas would be by cars or public transport (where it provides sufficient accessibility). Unfortunately, by definition these transport means contradict with the objectives of minimising the costs (as fuel prices continuously grow) or travel time (public transport network is exposed to unfavourable traffic conditions e.g. in peak hours or bad weather). Care companies and health institutions need to support the "last mile" delivery of care services (just as logistics companies) as it directly impacts both the care-chain and the patient experience: a good care service can achieve multiple care-chain objectives, such as low cost, sustainability and high responsiveness.

The nurses of the CCE travel by bus and on foot, but due to delays in public transport it is inefficient and lowers the quality of services and causes excess inactive periods. Also, there are some locations in the town that are not well connected to public transport, therefore the time spent by walking is increased due to the distance between the patient's address and the nearest bus stop. It causes an overall longer time consumption of a patient visit that results in unnecessarily high ratio of traveling time to caretaking tasks. Patients expect reliable HHC delivery nonetheless, in cases when urban authorities want to improve and support neighbourhoods or city cores, so they restrict vehicle movements of central locations and create pedestrian zones, all this in order to keep low congestion, CO_2 emission and noise pollution. These nuances shall be part of the planning process.

The method presented in this paper, is based on the technique of Branch and Bound (Clausen 1999; Rouillon et al. 2006), which enables the development of an algorithm that improves the HHC routing and scheduling in conjunction with decision rules for the transport and assignment problems to reach the shortest possible time with the lowest possible costs for the satisfaction of demand. This problem is traditionally known as "the knapsack problem", which combined with the generalized assignment problem (GAP), provides the mathematical base for the development of the proposed algorithm.

The algorithm is based on the approaches of Albareda-Sambola et al. (2006), Li and Curry (2005), Osorio and Laguna (2003) and Martello and Toth (1981) but it also includes some findings of Ross and Soland (1975) and Fisher et al. (1986). In the continual search for optimal solutions to GAP, the use of heuristics has been of special importance as it follows from Cattrysse and Van Wassenhove (1992), Cattrysse et al. (1994), Amini and Racer (1995) and Lorena and Narciso (1996). This has accelerated the search for solutions to the optimization problem.

Developing the HHC route assignment algorithm presented in this paper, the authors started from the results of Ribeiro and Pradin (1993), who rely on a two-phase method: first of all, selecting and assigning similar Home Care assistance (phase 1) and secondly establishing a new division and reallocation in order to minimize possible inefficiency (phase 2). Here the idea of Osorio and Laguna (2003), who introduced in their algorithm, different levels of efficiency of multiple resources or agents after the assignment, has also been considered. Our assignment is determined by the different capacities of available care time options, patient services, minimizing division of services, and improving efficiencies in home-care services.

STAGE 1: The grouping of PATIENTS by route.
The CCE defines different transport routes; the patients are assigned to a particular route according to their proximity to each route. The allocation of each patient (P_j) to a route (R_k) can be noted as P_{jk}, where k is the route index.

STAGE 2: Calculation of daily HOME-CARE SERVICES.
Secondly it is calculated the daily home-care load (time required to complete the services provided to a patient j, for each patient, denoted by $Load(P_{jk})$), as well as the daily load for each route, $Load(R_k)$, defined at stage 1.

Step 2.1. Calculation of the load issued by each nurse (supplier) (units: min):

$$Load\,(Pjk) = \sum_{m=1}^{d} Load(HCmj) \tag{1}$$

Step 2.2. Calculation of the load assigned to each route (units: min):

$$Load(R_k) = \sum_{j=1}^{b} Load\left(P_{jk}\right) = \sum_{j=1}^{b}\sum_{m=1}^{d} Load\left(HC_{mj}\right) \tag{2}$$

STAGE 3. Calculation of daily HOME-CARE LOADS.
Step 3.1. Selection of the route with the greatest load and assignment of the Nurse N_o with a time available similar to this load:
N_o is assigned if

$$\begin{aligned} &Load(R_k) \leq Capacity(N_o) \\ &\forall o \to o = \{1\ldots a\}, \forall k \to k = \{1\ldots c\} \end{aligned} \tag{3}$$

According to the following rules:
RULE 1: Assignment N_o to route according Load R_k (in decreasing order).
RULE 2: If Capacity N_o < Load R_k follow to the following steps.
Step 3.2. If the HC load of a route is greater than the capacity of the non-assigned nurses:

$$\begin{aligned} &Load(R_k) > Capacity(N_o) \\ &\forall o \to o = \{1\ldots a\}, \forall k \to k = \{1\ldots c\} \end{aligned} \tag{4}$$

the **division** of the routes' load is following the procedure as indicated in Eqs. (5 and 6):

$$Load(R_k) = Load_1(R_k) + Load_2(R_k) \tag{5}$$

$$\begin{aligned}&Load_1(R_k) = Capacity(N_o)\\&Load_2(R_k) = Load(R_k) - Load_1(R_k)\\&\forall o \to o = \{1\ldots a\}, \forall k \to k = \{1\ldots c\}\end{aligned} \tag{6}$$

Step 3.3. If the HC load for any patient is greater than the capacity of the assigned nurse:

$$\begin{aligned}&Load\left(P_{jk}\right) > Capacity(N_o)\\&\forall o \to o = \{1\ldots a\}, \forall j \to j = \{1\ldots b\} \forall k \to k = \{1\ldots c\}\end{aligned} \tag{7}$$

The division of the order is carried out in the following way

$$Load(P_{jk}) = Load_1\left(P_{jk}\right) + Load_2\left(P_{jk}\right) \tag{8}$$

and where:

$$Load_1\left(P_{jk}\right) = Capacity(N_o) \tag{9}$$

$$\begin{aligned}&Load_2\left(P_{jk}\right) = \sum\nolimits_{non-assigned} Load\left(HC_{mj}\right)\\&\forall o \to o = \{1\ldots a\}, \forall j \to j = \{1\ldots b\} \forall k \to k = \{1\ldots c\}, \forall m \to m = \{1\ldots d\}\end{aligned} \tag{10}$$

Step 3.4. If a HC load assigned to a route $Load(R_k)$ is less than the capacity of the allocated Nurse N_o, but failing to meet the constraint of the maximum number of patients P_{jk} to be visited (in exceeding that number $P_{ok} > W_{ok}$), the load is divided as follows:

$$Load(R_k) = Load_1(R_k) + Load_2(R_k) \tag{11}$$

where:

$$Load_1(R_k) = Load\left(n^o maxP_{jk}\right) \tag{12}$$

$$\begin{aligned}&Load_2(R_k) = \sum\nolimits_{non-assigned} Load_1(R_k)\\&\forall j \to j = \{1\ldots b\}, \forall k \to k = \{1\ldots c\}\end{aligned} \tag{13}$$

Step 3.5. Having completed the allocation of nurses to the route with the greatest load, the allocation of nurses continues with the route with the next largest load. For this, steps 3.1, 3.2, 3.3, and 3.4 are carried out. This **process** should be **continued until all the routes** with home-care loads greater than **10 minutes** have been processed.
Step 3.6. The allocation of quick orders and remainders of non-assigned HC service:

$$\mathrm{QS}_n = [\mathrm{QS}_1, \mathrm{QS}_2, \mathrm{QS}_3, \mathrm{QS}_4] \tag{14}$$

QS (quick services) are defined as having an associated load of less than 10 min, and as such are the last to be assigned within the calculation of the algorithm:
QS_1 = Load (P_{jk}) $\leq$ 10 minutes
QS_2 = $Load_2$ (R_k) = Load (R_k) − $Load_1$ (R_k) $\leq$ 10 minutes
QS_3 = $Load_2$ (P_{jk}) = $\sum_{non-assigned} Load(HCmj) \leq$ 10 minutes
QS_4 = $Load_2$ (R_k) = $\sum_{non-assigned} Load(Pjk) \leq$ 10 minutes

$$Capacity\,(No) \geq \sum\nolimits_{n=1}^{4} QSn \tag{15}$$

STAGE 4. Calculation of COST.
Now, with all the orders assigned to the selected nurses N_o (Stage 3), in this stage the total cost (Ct) shall be calculated regarding the use of the selected transport types T_i:

$$Ct = \sum_{k=1}^{c} Ck \quad Ck = \sum_{i=1}^{a} \delta i * Ci;\ where\ \begin{array}{l} \delta i = 0;\ if\ T_i\ is\ not\ used \\ \delta i = 1;\ if\ T_i\ is\ selected \end{array} \tag{16}$$

STAGE 5. Calculation of the assignment efficiencies of the means of road transport.
Efficiency calculations are performed here to check the optimal assignment of transport type to each Nurse route. The definition of efficiency depends on the CCE; here we calculated as transport type in relation to the maximum number of patients that this transport type allows visiting in a route.
Step 5.1. Calculation of the efficiency (α) for each selected N_o in Stage 3:

$$No \rightarrow \alpha o;\ \alpha o \in [0, 1];\ \forall o \rightarrow o = \{1..e\}$$

where:

$$\alpha ok = \frac{Load(No, Rk)}{Capacity(No, Rk)}$$

Step 5.2. If the efficiencies calculated for each T_i are equal or greater than 0.6, the assignment is final, as this is a level considered acceptable by the CCE. As such, this ends the calculation with the algorithm. For each T_i that the efficiency calculation gives a result of less than 0.6, the assignment of transport type T_i should be repeated.

3 Results and Conclusion

The algorithm described above was applied on the data of the CCE, where currently ten nurses deliver HC in eight hours daily. Based on our calculations, there are substantial savings achievable by using different transportation modes: if all the nurses use public transport, the weekly care requires ten nurses, but if they all travelled by electric bikes, only eight of them would be enough to serve all the patients. We do not aim to reduce the staff of any healthcare institution, as most of them already struggle with labour shortages, our approach was to see whether the savings (coming from monthly tickets for buses) can cover an investment to a fleet of e-bikes. The answer is yes, but only on the long run: Fig. 1 shows under what circumstances would the investment be feasible, where the Net Present Value was calculated for 20 years.

Inefficiencies cause a huge cost burden to HHC providers, and better resource allocation and investment decisions can be a good option for sustainable financing. The non-motorised transport modes (such as walking and biking) are not present in the focus of transportation research (Rietveld 2000) and HHC delivery studies despite their many advantages: negative externalities are not produced, delays due to congestions are easily avoidable and the CO_2 emission is close to zero.

Regarding the objectives, the algorithm proposed here is able to efficiently allocate the nurses with different set of skills, for better satisfaction of demand and improve the service quality in the home care supply chain in urban environment. At the same time, the use of e-bikes is environmentally friendly, resilient (not affected by traffic congestions), provides better estimations and planning of arrival times

Fig. 1 NPV of the investment in case of different amount of bikes acquired at 2% discount (left) and different discount rates in case of 8 e-bikes purchased (right)

without encumbering the nurses by the distress of driving and finding parking spots. The return of investment is proven by the methodology of NPV in the case of the CCE in Zalaegerszeg, Hungary.

References

Albareda-Sambola, M., Van Der Vlerk, M. H., & Fernández, E. (2006). Exact solutions to a class of stochastic generalized assignment problems. *European Journal of Operational Research, 173,* 465–487.

Amini, M. M., & Racer, M. (1995). A hybrid heuristic for the generalized assignment problem. *European Journal of Operational Research, 87,* 343–348.

Cattrysse, D. G., Salomon, M., & Van Wassenhove, L. N. (1994). A set partitioning heuristic for the generalized assignment problem. *European Journal of Operational Research, 72,* 167–174.

Cattrysse, D. G., & Van Wassenhove, L. N. (1992). A survey of algorithms for the generalized assignment problem. *European Journal of Operational Research, 60,* 260–272.

Clausen, J. (1999). Branch and bound algorithms-principles and examples. *Department of Computer Science, University of Copenhagen*, 1–30.

Eveborn, P., Flisberg, P., & Rönnqvist, M. (2006). Laps care—An operational system for staff planning of home care. *European Journal of Operational Research, 171,* 962–976.

Eveborn, P., Rönnqvist, M., Einarsdóttir, H., Eklund, M., Lidén, K., & Almroth, M. (2009). Operations research improves quality and efficiency in home care. *Interfaces, 39,* 18–34.

Fikar, C., & Hirsch, P. (2017). Home health care routing and scheduling: A review. *Computers & Operations Research, 77,* 86–95.

Fisher, M. L., Jaikumar, R., & Van Wassenhove, L. N. (1986). A multiplier adjustment method for the generalized assignment problem. *Management Science, 32,* 1095–1103.

Genet, N., Boerma, W., Kroneman, M., Hutchinson, A., & Saltman, R. B. (2013). *Home care across Europe: Current structure and future challenges*. London: European Observatory on Health Systems and Policies.

Hiermann, G., Prandtstetter, M., Rendl, A., Puchinger, J., & Raidl, G. R. (2015). Metaheuristics for solving a multimodal home-healthcare scheduling problem. *Central European Journal of Operations Research, 23,* 89–113.

Li, V., & Curry, G. L. (2005). Solving multidimensional knapsack problems with generalized upper bound constraints using critical event tabu search. *Computers & Operations Research, 32,* 825–848.

Lorena, L. A. N., & Narciso, M. G. (1996). Relaxation heuristics for a generalized assignment problem. *European Journal of Operational Research, 91,* 600–610.

Martello, S., & Toth, P. (1981). An algorithm for the generalized assignment problem. *Operational Research, 81,* 589–603.

OECD. (2015). *Health at a glance 2015: OECD indicators*. Paris: OECD Publishing.

Osorio, M. A. A., & Laguna, M. (2003). Logic cuts for multilevel generalized assignment problems. *European Journal of Operational Research, 151,* 238–246.

Ribeiro, J. F., & Pradin, B. (1993). A methodology for cellular manufacturing design. *The International Journal of Production Research, 31,* 235–250.

Rietveld, P. (2000). Non-motorised modes in transport systems: A multimodal chain perspective for the Netherlands. *Transportation Research Part D: Transport and Environment, 5,* 31–36.

Ross, G. T., & Soland, R. M. (1975). A branch and bound algorithm for the generalized assignment problem. *Mathematical Programming, 8,* 91–103.

Rouillon, S., Desaulniers, G., & Soumis, F. (2006). An extended branch-and-bound method for locomotive assignment. *Transportation Research Part B: Methodological, 40,* 404–423.

Trautsamwieser, A., Gronalt, M., & Hirsch, P. (2011). Securing home health care in times of natural disasters. *OR Spectrum, 33,* 787–813.

Wegener, M., & Fürst, F. (1999). Land-use transport interaction: State of the art. *Available at SSRN 1434678*.

Wirnitzer, J., Heckmann, I., Meyer, A., & Nickel, S. (2016). Patient-based nurse rostering in home care. *Operations Research for Health Care, 8,* 91–102.

Hospital Accreditation and Its Impacts on Quality Culture

J. D. R. Terra and F. T. Berssaneti

Abstract Brazilian health care system has been going through profound changes, causing hospital institutions to adopt quality management programs. The goal is to continually improve these processes, products and services. This article analyzes the impact promoted by hospital accreditation methodology in the development of a quality culture directed towards providing services with excellence. It uses a qualitative approach, with multiple case studies, in five different hospitals, from November 2015 to March 2016. The approach was done through interviews, with the support of a semi-structured survey. The results showed that accreditation methodology is the main means by which a hospital initiates and diffuses quality management. The conclusion shows that the accreditation methodology is able to promote the processes, which give rise to the development of a culture of quality, increasing patients satisfaction.

Keywords Hospital accreditation · Quality management · Productivity
Health care services

1 Introduction

The concept of quality in health involves the direct relationship between service providers and patients, insofar as the service provided adapts to the needs and expectations of those who receive it, and is no longer just a product attribute, With the responsibility of an individual, and to cover all the processes of the activity of the organizations, that is, be a joint objective of all those involved (Mendes 2012).

J. D. R.Terra (✉) · F. T. Berssaneti
Department of Production Engineering, University of Sao Paulo,
Av. Prof. Luciano Gualberto, 128, São Paulo, Brazil
e-mail: daniel.terra@usp.br

F. T. Berssaneti
e-mail: fernando.berssaneti@usp.br

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Not only quality is important but also quality assurance and the participation of workers in quality assurance is fundamental to obtain better results (Donabedian 1996).

Health policies seek to improve the quality of health care through the application of a range of interventions in quality systems, encouraging safer and more appropriate clinical services for the patient (Lipworth et al. 2013).

Although workers' resistance to the implementation of quality programs is indicated as the greatest difficulty in their implementation (Maekawa et al. 2013), changes in attitudes and behaviors may not be sufficient, so that structural interventions are needed.

The implantation of hospital accreditation stamps and quality management standards are becoming increasingly frequent within this context of changes that hospital institutions have been experiencing, whether in their operations or in the way, they relate to their patients.

The barrier to be overcome is shown by the evidence of quality and productivity gains generated by these initiatives, the productivity of the health professional being identified not only as part of the problem, but also as the potential solution (Moffatt et al. 2014). In addition, there is a lack of empirical evidence in the literature relating the implementation of such initiatives with professional performance (Jaafaripooyan et al. 2011).

The objective of this study was to analyze the impacts of hospital accreditation and quality management standards in the creation of a quality culture that is capable of directing quality management to best practices.

The culture of quality is understood as a determinant factor for the provision of good services, since it links the increase of productive efficiency to a greater retention of clients, improvements in the quality of service and greater security in the services, both for those who offer and to those who receive them.

2 Methods

A qualitative approach was adopted, with a multiple case study. Five hospitals were analyzed: three public and two private. All of them are large, located in the metropolitan city of São Paulo, Brazil. The criterion for choosing the sample was the orientation that hospitals have in relation to hospital accreditation and quality management standards:

- Hospital A, public, specialist of *Sistema Único de Saúde* (*SUS*), accredited by the Joint Commission International (JCI) and the *Organização Nacional de Acreditação* (*ONA*), level III (highest level);
- Hospital B, private, accredited by JCI;
- Hospital C, public, specialist of *Sistema Único de Saúde* (*SUS*), certified by the International Organization for Standardization (ISO) 9001 and accredited by ONA, level I;

- Hospital D, public, general of *Sistema Único de Saúde* (*SUS*), Social Healthcare Organization (OSS), accredited by JCI and ONA, level III;
- Hospital E, private, general, certified by the Occupational Health and Safety Assessments Series (OHSAS) 18001 and accredited by JCI.

Data collection occurred between November 2015 and February 2016. It was performed through recorded interviews and with the aid of a semi-structured questionnaire, elaborated from the relevant literature. The semi-structured questionnaire was divided into three parts:

- Characterization of the interviewee (position, specialty, improvement courses) and hospital (size, service units, quality seals obtained);
- Characterization of services and products offered; and
- Characterization of quality programs, methodologies and tools implemented and used by the hospital.

From the semi-structured questionnaire, it was possible to identify the relationship between the products and services offered and how they relate to the programs, methodologies and quality tools implemented by the hospital.

The interviews were conducted with professionals responsible for quality management and sought to identify how accreditation stamps (JCI and/or ONA) and quality management standards (ISO 9001 and/or OHSAS 18001) impact on the excellence of services provided by hospitals:

- Increase in productivity (Fortes et al. 2011; Brackett et al. 2013; Dubois et al. 2013);
- Increased level of patient satisfaction (Calabrese 2012; Gok and Sezen 2013; Rocha et al. 2013; Yousefian et al. 2013; Handayani et al. 2015);
- Standardization of services (Amerioun et al. 2011);
- Increased patient safety (Speroff et al. 2010; Greenfield et al. 2011; Shaw et al. 2014);
- Increase in productive efficiency (Maekawa et al. 2013);
- Customer retention and impact on the 'brand', qualifying the hospital as a reference for the society that serves (Varkey and Kollengode 2011);
- Quality of health care (Seoane and Fortes 2014).

The inputs used were analyzed based on the impact they cause on the processes and what results they generate. The variations regarding the interpretation of results occurred in relation to the type of service that the hospital offers, since there are particularities in the care of each institution. For these cases, it was not possible to admit generalizations regarding the applicability of the entries, and they were not considered.

The interviewee and the researcher did not have any type of relationship that could influence the interpretation of the data or the result of the work.

All the hospitals surveyed signed the *Termo de Consentimento Livre e Esclarecido* (*TCLE*). The study was registered in the Brazil Platform under the number of the *Certificado de Apresentação para Apreciação Ética* (*CAEE*) 50035315.1.0000.0065.

3 Results and Discussions

The interviews aimed to relate the inputs (implemented initiatives) to the outputs of the process (results achieved), by means of evidences that prove the gains of excellence in the services provided. Table 1 presents the results of the study.

Table 1 Initiative implemented by the hospitals and the respective results achieved, until March 2015

			Hospitals				
	Initiatives	Results	A	B	C	D	E
Accreditation	Beginning of quality management	Increased level of patient satisfaction	Y[1]	Y	–	Y	Y
	Excellence in health services	Increased productivity and level of patient satisfaction	Y	Y	Y	Y	Y
	Quality is strategic for the institution: recognition against other institutions	Standardization of services	–	Y	–	Y	Y
	Support from top management	Standardization of services	Y	Y	Y	Y	Y
	Definition of standards and metrics: process management	Increased productivity	Y	Y	–	Y	Y
	Scope of certificates	Increased levels of patient safety	Y	–	–	–	Y
Quality management	Implantation of electronic forms, with definition of standards and metrics	Increased productivity	–	–	Y	–	–
	Ability to evaluate comprehensive processes	Increased levels of patient safety	–	–	Y	–	Y
	Detailed mapping of processes	Increased productivity Increased levels of patient safety Reduced use of raw materials	–	–	Y	–	Y
Culture of quality	Assistance process	Increased production efficiency Customer retention	Y	Y	Y	Y	Y
	Trainings	Increased production efficiency Increased levels of patient safety Improvements in the quality of health care	Y	Y	Y	Y	Y
	Patient orientation regarding procedures performed by workers	Increased levels of patient safety and customer retention	Y	Y	Y	–	–

(continued)

Table 1 (continued)

			Hospitals				
	Initiatives	Results	A	B	C	D	E
		Improvements in the quality of health care					
	Processes well equated and embedded in the routine of workers	Increased production efficiency Increased levels of patient safety Improvements in the quality of health care	Y	Y	Y	Y	Y
	Standardization of results	Increased production efficiency	Y	Y	Y	Y	Y
	Quality management: support to other areas	Improvements in the quality of health care Customer retention	Y	Y	Y	Y	Y
	Application of quality indicators	Increased production efficiency	Y	Y	Y	Y	Y
	Dissemination of the use of quality tools and methodologies	Increased production efficiency Increased levels of patient safety Improvements in the quality of health care	Y	Y	Y	Y	Y

[1]Y: yes

According to the answers presented by the interviewees, the hospitals have different understandings and views on the topics presented. This is due to the type of service that is offered by the institution, as well as the type of care offered to the patient.

The results of the interviews made it possible to show that the accreditation stamps, initially adopted as a strategic differential, started the quality management in four hospitals surveyed, except in Hospital C, which opted for ISO9001. Accreditation proved to be the main quality program implemented by hospitals, helping to define standards, facilitating the use of metrics and generating management focused on processes and results.

It was also emphasized its importance in the process of improving health services and that, when adapted to the local reality, it achieves better results. This statement corroborates Mendes (2012) and Pai and Chary (2013). They affirm that the quality of a service offered by a hospital must be established by the standards adopted and adapted according to the need of the environment in which the hospital is inserted.

Another important point is the support of top management, which was essential for hospitals to direct their efforts in the quest for greater excellence in services rendered. This shows that the governing body of hospital institutions is inclined to direct their efforts towards results-oriented quality management, with clear definition of standards and metrics, increasing the efficiency of the processes practiced.

Quality management standards were less widely used. Hospitals A, B and D reported that they considered such standards difficult to interpret and considered to have limited applicability in the healthcare.

The hospitals that use them (C and E) affirm that quality management standards stand out for the ability to evaluate comprehensive processes and generate detailed mapping of them, being fundamental in detecting process failures and contributing to subsequent increase of productivity in them.

This information corroborates Shaw (Shaw et al. 2014), who affirm that hospital accreditation and quality standards, when used together, promote structures and processes that support patient safety and clinical organization.

Other identified evidence concerns the actions taken to create a culture of quality. The interviewees emphasized that the continuous training, associated to the implantation of quality routines with the workers are fundamental for the application of the concepts of quality in the hospitals.

The mapping of critical processes and the assistance of specialized groups were also cited as being important in detecting the points to be improved.

Organizationally, it can be evidenced that the areas responsible for quality management in hospitals contribute to the dissemination of the quality culture through the definition and implementation of processes well equated and embedded in the routine of the workers.

It was identified that, when training appropriate to the needs of each institution, standardized processes, methodologies and quality tools were implemented, higher levels of patient satisfaction and better use of resources were achieved.

The variations in the interpretation of the results, due to the diversity of the services offered and the public attended by the hospitals, limit generalizations and may cause unintentional deviations.

However, it can be concluded that when associated quality initiatives have proved to be a strategic element in achieving better results. In addition, there was a cause and effect relationship between the initiatives, since accreditation and quality management standards were found to be relevant to the culture of quality in hospitals.

Although the research is limited to the understanding from the point of view of the interviewee, it is understood that, because the institution has formalized the participation through the signature of the TCLE and indicated the respondent, the responses are consistent with the reality of the institution.

References

Amerioun, A., Tofighi, S., Mahdavi, S. M. S., Mamaghani, H., & Meskarpour Amiri, M. (2011). Assessment of International Joint Commission (IJC) accreditation standard in a military hospital laboratory. *Journal of Military Medicine, 13*(2), 75–80.

Brackett, T., Comer, L., & Whichello, R. (2013). Do lean practices lead to more time at the bedside? *Journal for Healthcare Quality: Official Publication of the National Association for Healthcare Quality, 35*(2), 7–14. https://doi.org/10.1111/j.1945-1474.2011.00169.x.

Calabrese, A. (2012). Service productivity and service quality: A necessary trade-off? *International Journal of Production Economics, 135*(2), 800–812. https://doi.org/10.1016/j.ijpe.2011.10.014.

Donabedian, A. (1996). The effectiveness of quality assurance. *International Journal for Quality in Health Care, 8*(4), 401–407.

Dubois, C. A., Bentein, K., Ben Mansour, J., Gilbert, F., & Bédard, J. L. (2013). Why some employees adopt or resist reorganization of work practices in health care: Associations between perceived loss of resources, burnout, and attitudes to change. *International Journal of Environmental Research and Public Health, 11*(1), 187–201. https://doi.org/10.3390/ijerph110100187.

Fortes, M. T., De Mattos, R. A., & Baptista, T. W. D. F. (2011). Acreditação ou acreditações? Um estudo comparativo entre a acreditação na França, no Reino Unido e na Catalunha. *Revista da Associação Médica Brasileira, 57*(2), 239–246. https://doi.org/10.1590/S0104-42302011000200025.

Gok, M. S., & Sezen, B. (2013). Analyzing the ambiguous relationship between efficiency, quality and patient satisfaction in healthcare services: The case of public hospitals in Turkey. *Health Policy, 111*(3), 290–300. Elsevier Ireland Ltd. https://doi.org/10.1016/j.healthpol.2013.05.010.

Greenfield, D., Pawsey, M., & Braithwaite, J. (2011). What motivates professionals to engage in the accreditation of healthcare organizations? *International Journal for Quality in Health Care, 23*(1), 8–14. https://doi.org/10.1093/intqhc/mzq069.

Handayani, P. W., Hidayanto, A. N., Sandhyaduhita, P. I., Kasiyah, & Ayuningtyas, D. (2015). Strategic hospital services quality analysis in Indonesia. *Expert Systems with Applications, 42*(6), 3067–3078. Elsevier Ltd. https://doi.org/10.1016/j.eswa.2014.11.065.

Jaafaripooyan, E., Agrizzi, D., & Akbari-Haghighi, F. (2011). Healthcare accreditation systems: Further perspectives on performance measures. *International Journal for Quality in Health Care, 23*(6), 645–656. https://doi.org/10.1093/intqhc/mzr063.

Lipworth, W., Taylor, N., & Braithwaite, J. (2013). Can the theoretical domains framework account for the implementation of clinical quality interventions? *BMC Health Services Research, 13*(1), 530. https://doi.org/10.1186/1472-6963-13-530.

Maekawa, R., de Carvalho, M. M., & de Oliveira, O. J. (2013). Um estudo sobre a certificação ISO 9001 no Brasil: mapeamento de motivações, benefícios e dificuldades. *Gestão & Produção, 20*(4), 763–779. https://doi.org/10.1590/S0104-530X2013005000003.

Mendes, V. D. M. P. (2012). *Qualidade no Serviço Nacional de Saúde: Evolução recente e perspectivas futuras*. Universidade Nova de Lisboa. Available at: http://run.unl.pt/handle/10362/9400.

Moffatt, F., Martin, P., & Timmons, S. (2014). Constructing notions of healthcare productivity: The call for a new professionalism? *Sociology of Health & Illness, 36*(5), 686–702. https://doi.org/10.1111/1467-9566.12093.

Pai, Y. P., & Chary, S. (2013). Dimensions of hospital service quality: A critical review: Perspective of patients from global studies. *International Journal of Health Care Quality Assurance, 26*(4), 308–340.

Rocha, L. R. M., Veiga, D. F., e Oliveira, P. R., Song, E. H., & Ferreira, L. M. (2013). Health Service Quality Scale: Brazilian Portuguese translation, reliability and validity. *BMC Health Services Research, 13*(1), 24. https://doi.org/10.1186/1472-6963-13-24.

Seoane, A. F., & Fortes, P. A. D. C. (2014). Percepção de médicos e enfermeiros de unidades de assistência médica ambulatorial sobre humanização nos serviços de saúde. *Saúde e Sociedade, 23*(4), 1408–1416. https://doi.org/10.1590/S0104-12902014000400023.

Shaw, C. D., Groene, O., Botje, D., Sunol, R., Kutryba, B., Klazinga, N., et al. (2014). The effect of certification and accreditation on quality management in 4 clinical services in 73 European hospitals. *International Journal for Quality in Health Care, 26*(March), 100–107. https://doi.org/10.1093/intqhc/mzu023.

Speroff, T., Nwosu, S., Greevy, R., Weinger, M. B., Talbot, T. R., Wall, R. J., et al. (2010). Organisational culture: Variation across hospitals and connection to patient safety climate. *Quality & Safety in Health Care, 19*(6), 592–596. https://doi.org/10.1136/qshc.2009.039511.

Varkey, P., & Kollengode, A. (2011). A framework for healthcare quality improvement in India: The time is here and now! *Journal of Postgraduate Medicine, 57*(3), 237. https://doi.org/10.4103/0022-3859.85222.

Yousefian, S., Harat, A. T., Fathi, M., Ravand, M., & Model, E. (2013). A proposed adaptation of Joint Commission International Accreditation Standards for. *Advances in Environmental Biology, 7*(6), 956–967.

Part VII
Education

Technology Transfer Outputs Versus Publications: Which One Wins the Battle?

R. de la Torre, D. Gil-Doménech and J. Berbegal-Mirabent

Abstract Today's universities are expected to simultaneously conduct teaching, research and third stream activities. These latter activities are usually materialized in the form of technology transfer activities. In a context were researchers are expected to simultaneously excel in all the tasks they perform, the scheme of incentives for the academic community is crucial. This study seeks to investigate and generate a new debate on in which activities are researchers devoting their efforts and time. In order to do so, we describe the evolution of research (publications) and technology transfer (R&D contracts and funded projects) outputs in the four technical universities of Spain. Results reveal that while revenues coming from R&D activities have notoriously diminished in the last years, the number of scientific publications has increased. These findings lead us to question whether Spanish universities are not properly aligned with industry needs, thus contradicting their *raison d'être*.

Keywords R&D activities · Technology transfer · Research · Publications University

R. de la Torre (✉)
Department of Management, ETSEIB, Universitat Politècnica de Catalunya, Av. Diagonal, 647, 08028 Barcelona, Spain
e-mail: maria.rocio.de.torre@upc.edu

D. Gil-Doménech · J. Berbegal-Mirabent
Faculty of Economic and Social Sciences, Department of Economy and Business Organisation, Universitat Internacional de Catalunya, Immaculada, 22, 08017 Barcelona, Spain
e-mail: mdgil@uic.es

J. Berbegal-Mirabent
e-mail: jberbegal@uic.es

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1 Introduction

Universities' mission has evolved as society has developed. Main drivers for this transformation refer to globalisation, technological and societal pressures, opportunities and norms. Today's universities are expected to simultaneously conduct teaching, research and third stream activities. Third stream activities materialize in a variety of forms; nevertheless, due to the difficulties in appropriately measuring them, there is a wide consensus in conceiving technology transfer activities as one of the primary objectives pursued through this mission.

Universities made their entry into regional policy in the 80s, when entrepreneurship became central to local development (Van Vught 2009). There were new incentives to create closer linkages between knowledge institutions, trade and industry. Since then, universities have drawn new "road maps" towards dynamic local forces capable to help their cities and regions to become more innovative and globally competitive in a global economy in which deliver social well-being. Through the development of collaborative university-industry R&D partnerships, researchers can share their expertise and knowledge and industry can benefit by implementing the solutions in their businesses. Given that active involvement of universities in regional needs has been proved to improve the economic development of the region, it is therefore paramount to question the type of R&D activities in which researchers are engaging.

Universities are expected to undertake third mission activities—regardless its size, academic spread or research interests—nevertheless, this role is taking place at different levels of commitment. The academic community must have the time, the freedom, and the motivation to produce the knowledge that can be transferred to the industry (Shattock 2009). In this setting, the scheme of incentives is therefore crucial, shaping researchers' decisions on where to allocate their time and efforts.

The Spanish higher education system perfectly illustrates the situation described above. Following their European counterparts Spanish universities have experienced a substantial evolution during the last decades (Corominas and Sacristán 2010; Llinàs-Audet et al. 2010). In terms of scientific publications Spanish universities are now ranked within the top ten of most productive countries in the world, achieving outstanding records in the fields of medicine, engineering, biochemistry, genetics and molecular biology (FECYT 2017). Nevertheless, it is in technology transfer outcomes where Spanish universities have not yet developed their full potential (Berbegal-Mirabent et al. 2013). This situation is further exacerbated by a decreasing trend in the number of industrial-funded projects (either national or international).

The underlying rationale behind these figures lies in the current incentive system. Academics should distribute their working day among teaching, research and technology transfer activities. With the exception of teaching duties (the schedule is defined based on the student demand), the rest of the working-time is expected to be devoted to the two other activities but, how this distribution is made? Several factors shape this decision. Intrinsic motivations (e.g., attitude, expected contribution), extrinsic motivations (e.g., promotion incentives, academic reputation) alongside with the university regulation, culture, and supporting services play a critical role in this decision (Olaya et al. 2017).

In Spain, extrinsic motivations are particularly relevant until professors obtain a permanent position, as a permanent position secures the job position. An external agency is in charge of evaluating the merits of the candidates. This process is known as “accreditation” and there are different intermediate positions before reaching a permanent position. Promotion opportunities are therefore highly tied to this accreditation process, as researchers need to successfully pass this process if they want to appoint for a job vacancy at a university. Analysing the weights assigned to the different activities considered in this evaluation process (de la Torre 2015), the conclusion is that publications in scientific journals weigh between 26 and 35% of the total evaluation points (depending on the knowledge field), while no more than 14% of the points refer to technology transfer activities. The limited academic recognition to technology transfer activities prevents academics to engage in such endeavours. Concerning the economic aspect, worker’s salary in public universities does include complements for teaching and research, but it does not for technology transfer activities.

Given the aforementioned considerations, we question whether Spanish universities—particularly those with a high industrial component such as technical universities—are not properly aligned with industry needs. If so, what are the triggers for this misalignment? Aiming at bringing some light into this issue, in this study we compare research outputs with technology transfer ones.

The remainder of the paper is organised as follows. Section 2 briefly summarises the methodology used to analyse the data. Next, in Sect. 3 we describe the main results. The conclusions and some ideas for future research developments are outlined in Sect. 4.

2 Methodology

Not all knowledge fields have the same likelihood of producing technology transfer results. Likewise, according to Stella and Woodhouse (2006) R&D activities might vary depending on the type of university. For instance, patents and spin-offs are outputs that characterise technical universities, rather than faculties in humanities or social sciences. Aiming at having a homogenous sample of universities, this paper only focuses on universities specially geared toward technology. In Spain these universities are called “polytechnical”. They mainly concentrate in degrees in the fields of engineering and architecture. Spain has four universities that respond to this typology, namely: Universitat Politècnica de Catalunya (located in the region of Catalonia), Universitat Politècnica de Valencia (in the Valencian Community), Universitat Politécnica de Madrid (in the autonomous community of Madrid) and Universidad Politécnica de Cartagena (in the region of Murcia).

The method followed for the analysis is mainly descriptive. It is just a first attempt that needs to be complemented in the future with more sophisticated analyses. Therefore, the study seeks to generate a new debate on how researchers are allocating their efforts in terms of R&D activities. For the purposes of this paper, technology transfer activities are operationalised through two main indicators: the number of R&D contracts, consultancies and provision of services; and the number of funded research projects. The proxy used to represent research outputs is the number of papers published in journals indexed in the Journal Citations Report.

To further explore the data, we conducted a second stage analysis where we performed several correlations. Specifically we investigated whether correlations among the variables (publications, R&D income, and research projects) were consistent over time, distinguishing by year, total volume per output and university.

3 Case Study

The present study focuses on four Spanish technical universities. The study covers historical data for the period comprised between 2007 and 2014. Table 1 summarizes the number of professors and students for all four universities. Three out of the four universities are among the biggest universities in Spain.

Since the beginning of the financial crisis, revenues from industry in the technical universities under study substantially decreased. Specifically, in 2014 the income from R&D contracts, consultancies and provision of services at universities were less than 50% of the total amount in 2007. Figure 1 illustrates this negative trend for the four technical universities under study.

Research projects, funded by national or international (mainly EU) public agencies did not experienced such a downward trend, although it suffered a significant setback in 2012, probably resulting from the austerity measures applied not only by the EU but the Spanish government. While the cumulative cut in the Spanish State Budget in R&D was 4.2% in 2010 and 7.3% 2011, in 2012 it was 25%. Consequently, this austerity measures in the national R&D investment had a

Table 1 Number of professors and students for the universities considered in the study (data from 2014)

University	Number of professors	Number of students
Universitat Politècnica de Catalunya (UPC)	2600	38,500
Universidad Politécnica de Cartagena (UPCT)	360	7200
Universidad Politécnica de Madrid (UPM)	3000	35,500
Universitat Politècnica de València (UPV)	2900	36,200

Fig. 1 Total income from R&D contracts, consultancies and provision of services per researcher

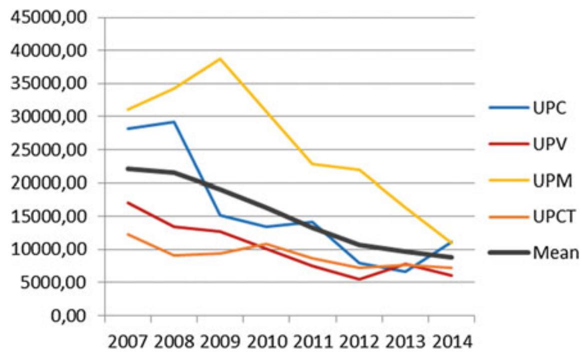


Fig. 2 Total number of funded projects per researcher

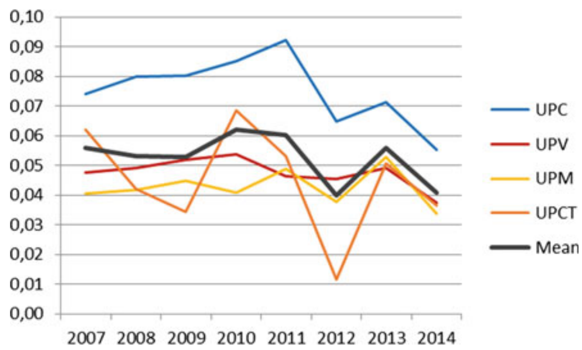
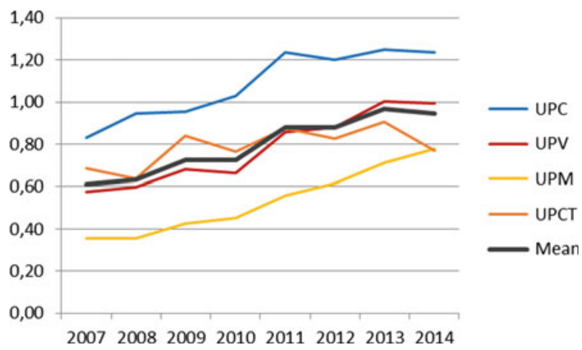


Fig. 3 Publication rates



negative impact in terms of funded research projects. The variation in the total number of research projects per researcher in the universities under study can be observed in Fig. 2.

Given that projects favour and force researchers to publish the main results, and that current model of public universities is mainly research-oriented, the number of publications in the period under analysis significantly increased. Figure 3 clearly mirror this trend. All four technical universities increased their publication rates (in the figure, calculated as the number of total publications divided by the number of professors). In average, the number of publications experienced a 40% increase.

As for the correlation analysis the results are:

- When comparing outputs by year, the number of publications and research projects show a positive and significant correlation, particularly for years 2007 (0.987, p-value = 0.013) and 2010 (0.977, p-value = 0.023). The other potential correlations are found to be not significant.
- When considering all the outputs, regardless the university and year, the number of publications and R&D contracts income correlate negatively (−0.542, p-value = 0.001), while when analysis the relationship between the number of publications and research projects the correlation is positive (0.441, p-value = 0.004), being consistent with the previous analysis.
- Lastly, when conducting the analysis in an individual fashion for each university, results indicate that for UPC and UPV the number of publications and R&D contracts income are negatively correlated (UPC: −0.701, p-value = 0.036; UPV: −0.861, p-value = 0.003). Contrarily, for UPM and UPCT no significant correlation is found.

These results reinforce that the greatest the time and effort researchers dedicate to publishing their works, the lower their collaboration with the industry. Furthermore, participating in competitive projects implies increasing the number of publications. This can be due to two main reasons: publications are necessary in order to apply for a research project, and results emerging from research projects are expected to be disseminated in the form of academic papers in scientific journals.

4 Implications

The results indicate that although the number of publications has increased through the past years in the universities under analysis (those with a technical focus), while the income coming from technology transfer activities has not followed the same evolution. We argue that one of the main causes might be due to the time devoted by researchers in performing this activity. That is, researchers prefer engaging in other research activities (such as publishing in academic journals) that might generate them greater benefits.

Given the Spanish incentive structure for academics, it is necessary to create policies that encourage scholars to conduct technology transfer activities. Some interventions might include rethinking the current accreditation system by suggesting a more balanced weight among teaching, research and third stream activities. That is, in order to be eligible for appointing to a higher position (or a more stable one), participation in technology transfer activities should be mandatory.

In addition, a system that boosts a fair and egalitarian economic remuneration among the three universities' mission is needed, where scholars can obtain additional rents for their efforts in R&D activities, and not only for outperforming in research, teaching or managerial tasks.

Likewise, it is necessary for universities to include policies that promote the development of technology transfer activities. Some examples include a favourable framework for the creation of spin-offs, or a new regulation for the creation of workgroups (i.e. institutes).

5 Conclusions and Further Research Avenues

This paper reflects on the evolution of research (publications) and technology transfer (R&D projects) activities in the four technical universities of Spain. Graphics show that revenues coming from R&D activities have notoriously diminished in the last years, and so has done the number of projects (both nationals and international ones). Contrarily, the number of scientific publications has increased.

Besides the financial crisis that Spain, as many other countries, suffered during the last years, we argue that one of the main drivers for such a decrement in technology transfer activities is the lack of incentives for professors. The current accreditation system promotes the dissemination of research results thought publications, rather than emphasizing the importance of working in university-industry projects. Said differently, researchers chose to devote their time and efforts to those activities that contribute to secure their job position. However, this situation contradicts the *raison d'être* of universities, as they are expected to contribute to the well-being of society by training future professionals, generating new knowledge and disseminating it to the industrial fabric.

Another reason that might explain the growth in the number of publications refers to the fact that research projects are usually framed in competitive projects (a small percentage corresponds to privately funded projects). Such competitive projects are increasingly requiring participants (universities, research centres and industry) to disseminate the research through publications in scholarly journals.

This paper was descriptive in its nature. Further studies might consider exploring the following issues that still remain underexplored:

- Extend the study to the rest of Spanish public higher education system. Are technical universities following the same pattern (in terms of publications and technology transfer activities) as non-technical universities?
- Conduct a longitudinal study to compare the performance of Spanish universities, taking into account the influence of changes in the regulatory framework of universities.
- Examine the incentives that drive researchers to engage in teaching, research and technology transfer activities.

References

Berbegal-Mirabent, J., Lafuente, E., & Solé, F. (2013). The pursuit of knowledge transfer activities: An efficiency analysis of Spanish universities. *Journal of Business Research, 66,* 2051–2059.

Corominas, A., & Sacristán, V. (2010). The strategic crossroads of Spanish public university. *Revista de Educación, 355,* 57–81.

de la Torre, R. (2015). *A methodology for the strategic staff planning in public universities* (PhD thesis). Universitat Politècnica de Catalunya, UPC.

FECYT. (2017). https://icono.fecyt.es/indicadores/Paginas/default.aspx?ind=122&idPanel=1#.

Llinàs-Audet, X., Girotto, M., & Solé, F. (2010). University strategic management and the efficacy of the managerial tools: The case of the Spanish universities. *Revista de Educación, 355,* 33–54.

Olaya, E. S., Berbegal-Mirabent, J., Alegre, I., & Duarte, O. G. (2017). Researchers' willingness to engage in knowledge and technology transfer activities: An exploration of the underlying motivations. *R&D Management*, in press.

Shattock, M. (2009). *Entrepreneurialism in universities and the knowledge economy*. Maidenhead: Society for Research into Higher Education and Open University Press.

Stella, A., & Woodhouse, D. (2006). *Australian universities quality agency. Ranking of higher education institutions*. Melbourne: AUQA.

Van Vught, F. (2009). The EU innovation agenda: Challenges for European higher education and research. *Higher Education Management and Policy, 21,* 1–22.

Rubrics as a Tool for Evaluating Hydraulic Engineering Projects in Both Bachelor's and Master's Degree

M. Pérez-Sánchez, V. S. Fuertes-Miquel, J. Soriano, E. Gómez and P. A. López-Jiménez

Abstract The herein described research proposes the development of evaluation methodologies based on designed rubrics for developing a strategy to be applied as a guide to evaluate Hydraulic Engineering Projects. These projects are present in horizontal and vertical interactions in the field of Hydraulic Engineering studies. At the horizontal level, the implementation of such rubrics can help to improve the acquisition of competences related to Design and Project in the studied matter. At the vertical level, the developing of an organized strategy can lead to a better coordination of learning outcomes in the acquisition of transversal competences according to the domain level, maintaining a uniformity of criteria within the different degrees in which subjects of this scope are offered in the UPV in its various campuses.

Keywords Transversal competence · Hydraulic engineering · Continuous learning · Master student

M. Pérez-Sánchez · V. S. Fuertes-Miquel · P. A. López-Jiménez (✉)
Department of Hydraulic and Environmental Engineering,
Universitat Politècnica de València, Camino de Vera S/N, 46022 Valencia, Spain
e-mail: palopez@upv.es

M. Pérez-Sánchez
e-mail: mopesan1@upv.es

V. S. Fuertes-Miquel
e-mail: vfuertes@upv.es

J. Soriano · E. Gómez
Department of Hydraulic and Environmental Engineering, ITA,
Universitat Politècnica de València, Camino de Vera S/N, 46022 Valencia, Spain
e-mail: jasool@ita.upv.es

E. Gómez
e-mail: elgosel@ita.upv.es

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1 Introduction

Design and Project aspects are crucial in the study plans of an engineering degree, especially when the completion of the degree courses or master's, conclude with a final works. These final works are related to possible design, dimensioning and/or (actual project implementation). Within these designs, hydraulic engineering projects are based on many curricular subjects of students participating in any engineering degrees in higher courses, being in many cases the base for other sorts of project implementations or facilities designs (Martínez et al. 2012). Furthermore, the consideration of rubrics for the evaluation of the Competence "Design and Project" has been individually analyzed (Rullán et al. 2010; Serrano et al. 2014). However, a few authors analyze such competence at all the domain levels of complete studies of the same student. In this sense, the present research depicts the results achieved when the same sort of rubrics is implemented along different levels in different matters within Hydraulic Engineering studies.

2 Objectives

The present research intends to carry out a development of the methodology of evaluation of the different activities related to Design and Project of hydraulic and fluid facilities, based on the implementation of general principles common rubrics. The final objective is the development of a strategy for adapting the different rubrics enabling evaluation of transversal competence 'Design and Project' according to the student's domain level (degree or master's), maintaining the alignment of learning according to established learning outcomes. Particularly, the manuscript describes the methodology carried out in the matter Fluid Facilities, which is taught in the first course of the Industrial Engineering Master's Degree along course 2016/2017, commenting the difference with used rubrics in Bachelor's degree.

3 Methods

Different rubrics will be developed to be applied in all the matters in Hydraulic Engineering projects, performed by students throughout different domain curricular levels. These rubrics will evaluate the different aspects considered as common interest in all the implemented matters. Finally, a ballot will be proposed to students in order to know how the development of such projects and rubrics have been useful for their understanding of the content of the different matters.

3.1 Development of the Innovation

The objective of the transverse competence 'Design and Project' applied in the matter of 'Fluid facilities' is the development and the evaluation of the competence in the third domain level when the student has been previously evaluated of the same competence in lower levels.

To carry out the project, the planning of the timeframe development of the defined project is performed through different face-to-face and non-face-to-face stages. In the face-to-face stage, the students acquire the necessary learning results, which enables them to use during the development of the project. The development of the project is implemented in the non-face-to-face stage through the available digital resources in the PoliformaT platform. During this phase, the student works competences such as autonomous learning, which is complemented with the guide of the teacher during the duration time of the activity to satisfactorily reach the learning results of the matters.

3.2 Definition of the Work Methodology

The activity is designed to develop a project designing the cold-water supply, domestic hot water, ventilation, wastewater collection and rainwater collection in a complex building, by a group of three or four students. The project has to correctly solve the design and sizing of the previous installations, according to the applicable regulations and following the concepts learnt during master class and practices session. Once the project report is prepared by each team, an oral defense of this work should be made, presenting it to the teachers of the subject, defending and justifying the solutions adopted in the memory.

All details of the project, the requirements of the facilities, and the documentation to be delivered by each student are published with an itemized definition of each part of the activity. In the same way, in the first class the key dates of delivery/defense of the works are established along with the presentation of the subject.

Several types of the building are designed, and different configurations are defined (e.g. number of floors, delivery pressures, orientations, requirements of supply/service companies) so that each group has a different project. To improve the tracking of the student, two deliveries (one partial and one final) are established in order to help the students to distribute the work time and the project doesn't develop near delivery data.

The different teachers attend the groups with particular questions about the project. The most common forms are face-to-face (either in class or through specific tutorial sessions) or by email in these sessions, solving the doubts about the application of the contents taught in class for the particularities of each project. In the same way, these taught concepts are completed, and the students are assisted for the particularities of the development of the report and or plans during the temporal programming of the activity.

Throughout the process, the student should contact the teacher to validate each of the items he designed with the project in each of the phases and stages.

The evaluation is a formative type, since the students must present the different results throughout on preliminary draft of the network, in which, the teacher helps them to achieve the objectives. To this end, two tutorials will be set as a minimum to improve the coordination of the development of the project. The first meeting is performed when the network is proposed; and the second meeting is organized when the resolution method of the problem and the obtained diameters (initially defined) are suggested. This fact enables the teacher to be able to evaluate the different indicators using the attached rubric. In addition to the analysis of the rubric, the teacher will evaluate the submitted project and the correct operation of the network.

4 Results

The different rubrics proposed to students at all domain levels will be presented, related to the results of the evaluation of the 'Design and Project' competences in different matters. Furthermore, the results of the questionnaire proposed to students are also an interesting outcome. The implementation of these strategies in students along the course 2016–2017 shows good results both in the level of acquisition of the competence and in the students' satisfaction of the implemented methodology.

4.1 Proposal of Rubric

The proposed rubric is based on indicators recommended by the ICE-UPV (Institute of the Science of the Education in the Universitat Politècnica de València). The descriptor of each indicator was adapted according to the different items of the project. The indicators as well as their descriptors are shown in Table 1.

The difference between the rubrics used in the Master's degree and Bachelor's Degree are related with the definition degree reached in the development of the project. In Bachelor's Degree, the pupils have to design a project with a level of draft, in which, they don't reach the execution. In this case, the used indicators are (i) Justifying the need of the project; (ii) Establishing the objectives of the project clearly; (iii) Proposing the actions for the achievement of the objectives; (iv) Assigning the deadline to complete the necessary actions; and (v) Identifying the possible inherent risks to project.

However, the used rubric in Master's Degree contains indicators that are higher in the Bloom's taxonomy (Anderson et al. 2001), and therefore, the students should develop a project more specific, in which, the teacher's help is reduced to give the pupils more freedom when they develop the project, establishing the constrains that could be found in real situation, once, the students will finish their academic training.

Table 1 Proposed tasks and participation percentage of the student in Master's Degree

Indicator	D. Not achieved	C. In development	B. Good/adequate	A. Excellent/exemplary	Evidence of each of the indicators
I1. Needs are assessed in a real context of intervention	Not valued or incorrectly done	An assessment is made faulty or incorrect in some cases	Adequate assessment is made, although not complete	An adequate, correct and complete assessment is made	It will be evaluated from the introduction point in the report and the defense
I2. The operational objectives of the project and deadlines are specified	Objectives or deadlines are not established	Some objectives and deadlines are specified	Operational aims of the project are defined and deadlines are set	All the objectives are specified and all the terms with future prospects are defined	
I3. Actions are planned and contingencies are anticipated	No actions are planned or anticipated contingencies	Actions and/or contingencies are planned, but with failures: not done in the most appropriate way	Actions are planned and contingencies are anticipated	The actions are planned and contingencies are also anticipated, proposing alternatives	Evaluation based on the analysis of the partial results obtained, and the improvement approach on the initial designs
I4. Available resources are adequately managed	Available resources are not managed	Resources are managed but with mistakes	The available resources are adequately managed	All available resources are adequately managed	Justification of the presented solution. Correct presentation of plans. Adequate interpretation of the legislation
I5. The implementation of the project is tracked	No follow-up is evident	There is some evidence of follow-up	A coherent monitoring of the project is carried out for the getting of the aims	A complete and coherent monitoring of the project is carried out	Correct and consecutive realization of each of the intermediate calculations (e.g., cold water: calculation of flow rates)
I6. Project risks are adequately managed	There is no evidence of risk management	The risks are managed but with mistakes: not done in the most appropriate way	Some of the risks of the project are properly managed	All the risks of the project are properly managed	It will be evaluated from selected operating schemes and the adaptation of these to the regulations

Thus, in Master's Degree, the students have to design projects when the context of the project is bit structured by the professor, considering its execution. The evaluated indicators in this case are (i) Assessing the need of the project in a real context; (ii) To specify the operative objectives of the project as well as to define the timetable; (iii) To plan the actions; (iv) To manage the available resources correctly; (v) To develop the tracking in the project implementation; and (vi) to manage the risks of the project adequately.

4.2 Quantification of the Learning Reached Results

The development of the project enabled to quantify the reached degree in the different used indicators to evaluate the acquisition of the 'Design and Project' competence. The maximum reached degree (A. Excellent) was reached by 62.28% of the students; adequate level (B) was get by 28.72% of the pupils; the third level (C. In development) was achieved by 4.84% and only 4.12% of the students didn't accomplish the development of this competence. Finally, if the marks obtained in the recovery exam and the marks of the project are analyzed, there is a positive trend (Fig. 1, Right), in which, the students with good marks obtained similar marks in the recovery exam. This correlation is lower when the student did the exam before carrying out the development of the project (Fig. 1, Left).

4.3 Knowing the Students' Opinion

To know the pupils' opinion, a survey was developed the end of the subject. The objective of the survey was to know the point of view of the student with the developed objective and its relation with the theoretical content taught in master class during the face-to-face stage.

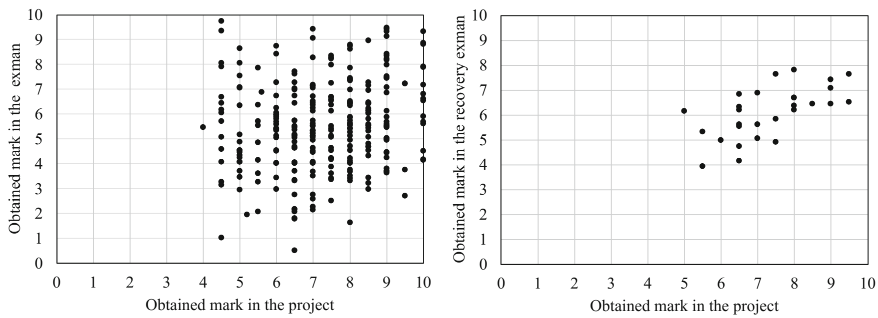

Fig. 1 **Left** Comparison between obtained mark in the project and obtained mark in the exam. **Right** Comparison between obtained mark in the project and obtained mark in the recovery exam

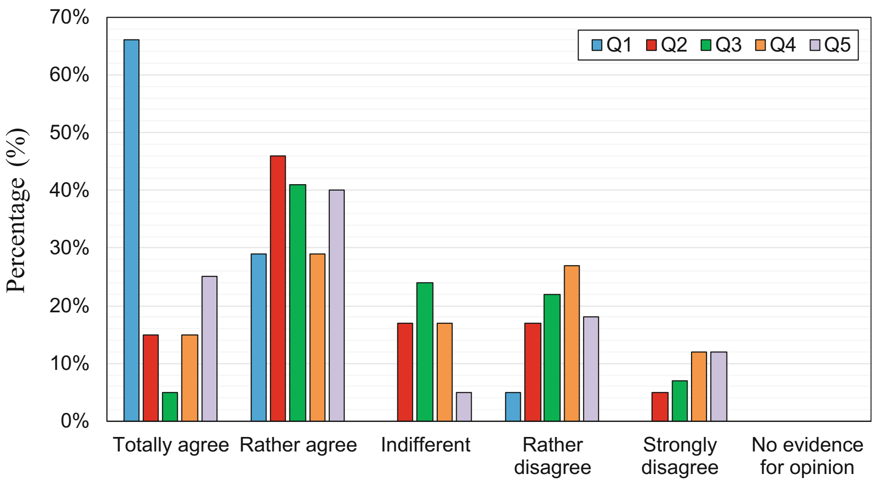

Fig. 2 Answers obtained in the survey

The questions of the survey were:

Q1: Does the proposed activity allow you to apply the knowledge developed in theory classroom and practice lessons?
Q2: Does the temporary planning to develop of the project design throughout the course allow you to start the activity well enough in advance to develop it properly?
Q3: Is the index developed by the teacher explaining the methodology and phases of the work, sufficiently clear and concise, to develop the proposed activity?
Q4: Did the project help you to acquire the knowledge, and to prepare other evaluations (e.g., tests, problems) of the subject?
Q5: Would you find interesting that the development of the project proposed in this subject involved other subjects of your grade?

Figure 2 shows the answers of the students that did the survey, in which, the participation was 39.33% of the total signed-up student. The results show the satisfaction of the students with the developed project, particularly, when they relate the developed theoretical concepts during master class with the applicability in the proposed project.

5 Conclusion

The herein described experience can be useful as an example of application of rubric systems in complex environments. The combination of active methodologies together with traditional methods has shown promising results in terms of the improvement of the learning results, and the acquisition of the Design and Project competence in the different domain levels, awarding the students greater freedom in the organization of their scholar timetable. To do so, an example was developed through developed experience in the ‘Fluid Facilities’ along 2016/2017 course. This subject was taught in the first course of Industrial Engineering Masters’ Degree with a participation of the 300 students. To improve the learning results, the student had to do a project through on work methodology that was described in the present document. A rubric to evaluate the getting of the learning results was proposed, defining the indicators and descriptors, as well as the evidences to define the reached degree by the student. Finally, an interesting correlation was developed, in which, the improvement of the obtained marks in the exam by the students was verified when they did the exam after developing the project.

In the last point, a survey throughout PoliformaT tool was developed, in which, the students showed their satisfaction with the development of the project as well as the applicability of the learnt concepts to carry out the project.

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References

Anderson, L. W., Krathwohl, D. R., Airasian, P., Cruikshank, K., Mayer, R., Pintrich, P., … Wittrock, M. (2001). *A taxonomy for learning, teaching and assessing: A revision of Bloom’s taxonomy*. New York: Longman Publishing. Artz, A. F., & Armour-Thomas, E. (1992). Development of a cognitive-metacognitive framework for protocol analysis of mathematical problem solving in small groups. *Cognition and Instruction, 9*(2), 137–175.

Martínez, A., Cegarra, J., & Rubio, J. (2012). Aprendizaje basado en competencias: una propuesta para la autoevaluación del docente. *Profesorado. Revista de curriculum y formación del profesorado, 16*(2), 374–386.

Rullan, M., Fernández, M., Estapé, G., & Márquez, D. (2010). La evaluación de competencias transversales en la materia trabajos fin de grado. *REDU. Revista de Docencia Universitaria, 8*(1), 74–100.

Serrano, A., Pérez, E., Biel, P., Fernández, A., & Hernández, M. (2014). Application of an erubric system for the evaluation of the work by modules in the degree in engineering in industrial design and product development. *REDU. Revista de Docencia Universitaria, 12*(1), 111–134.

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