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Henrik Gudmundsson  
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Josias Zietsman



# Sustainable Transportation

Indicators, Frameworks,  
and Performance Management

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# Sustainable Transportation

Indicators, Frameworks,  
and Performance Management

 Springer

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## Preface

This book is the result of 6 years of collaboration between four scholars from leading universities in Europe and North America. It is based on decades of collective experience in the areas of sustainable development and sustainable transportation, focused on research, teaching, and practice. The book's development was driven by the need for a comprehensive text for students, academics, and practitioners interested in the broad area of sustainable transportation.

The book provides a rich text for advanced undergraduate and graduate students, academics, researchers, and transportation practitioners. It will provide readers with a deep understanding of the basic concepts of sustainability as well as a coherent framework for how to apply the concepts consistently within the context of transportation planning, management, and decision-making.

The book contains 12 chapters and is organized into two main parts connecting theory and methodology to practical examples of sustainable transportation indicator systems followed by our concluding reflections. It is intended to be both a valuable reference on the subject and a source of ideas for how to approach the development of sustainable transportation indicator systems. The book is grounded in the belief that there is no one right way to develop such a system; however, there is a set of ideas and tools that should be applied to ensure that any system developed is informed by sustainability principles, is effective, and is used by all participants and stakeholders.

In the academic realm, the book is designed for use in courses involving the application of sustainability to decision-making in transportation. The structure of the chapters in Part I (Chaps. 2–7) was designed from a pedagogical/learning perspective. Each chapter builds on the previous set of ideas to enable students to develop a broad and interconnected understanding of the material and how it can be applied in a real-world setting. Where relevant, the text provides key terms, important references, and discussion questions to facilitate in-class discussions. The book can also be used in a range of existing courses on transportation planning, policy analysis, or performance management in general.

In the practitioner realm, the book will support planners, managers, consultants, and other professionals who are challenged with transitioning their transportation systems toward sustainability. It offers a frame of reference on what sustainability is and how a measurement system can be developed to make informed decisions. It

provides clear guidance on what we should measure, how we should measure, and what we should report. We have endeavored to make the text accessible, while not undermining the importance of using consistent and accurate terminology throughout. We hope to empower the reader with the correct terminology to facilitate effective communication. The descriptions, examples, and case studies in Part II of the book (Chaps. 8–11) in particular are intended to enable practitioners to develop sustainable transportation performance measurement systems that are well conceived and, hence, valuable to their organization.

In this book, we show that transportation plays a key role in addressing the broader topic of sustainability, while at the same time recognizing that transportation has to become more sustainable to make progress toward sustainable development. The message that there are multiple ways to implement a sustainable transportation performance measurement system may frustrate some who are looking for an “off-the-shelf” answer. Similar to sustainable development, moving toward sustainable transportation is a *process* of change that thrives when supported by a flexible and learning-oriented approach. We hope that the performance measurement frameworks and best practices discussed in this book provide useful starting points for those looking to embark on transforming their transportation systems toward sustainability. We provide our reflections on what we have learnt in the conclusion of the book (Chap. 12). Our intention is to continue developing and sharing ideas through a website associated with the book at <https://sustransindicators.com/> and we would encourage readers to engage with us in this enterprise.

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We thank our respective institutions (Technical University of Denmark, University of Leeds, Virginia Tech, and the Texas A&M Transportation Institute) for enabling us to enrich this text through our teaching and research activities. We would also like to thank our students for the feedback they provided on early drafts of this text. We believe the flow of the book and delivery of information has been greatly improved as a result of their insights.

We also wish to thank our numerous friends and colleagues in the sustainable transportation research community for their work, ideas, and encouragement. While not directly involved in the writing of this book, we have benefited significantly from their intellectual contributions that continue to shape and advance the fields of sustainable transportation and performance assessment.

Finally, we owe a great debt of thanks to all of our families who have supported us through the visits, exchanges, long nights, and weekends which have made this book possible.





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Sustainability has become an overarching concern for transportation policy and planning around the world. Like sustainable development, the concept of sustainable transportation is broadly defined, which permits policies and practices to be labeled as “sustainable” while pursuing business-as-usual approaches. Thus, there is a pressing need to better integrate and apply sustainability principles to transportation. Performance measurement frameworks offer an effective way to do this.

Over the past two decades, much effort has been made on understanding and applying the concept of sustainable development to transportation.<sup>1</sup> In this regard, there is a wealth of research and experience that we can learn from. Yet, substantive progress on realizing more sustainable forms of transportation remains limited. In many regions, the negative impacts from transportation are likely to worsen in the face of increasing demand for mobility and infrastructure (Dulca 2013; AfDB et al. 2012). For example, it is estimated that around 25 million paved road lane kilometers and 335,000 rail track kilometers will be needed globally by 2050 in response to growth in passenger and freight travel, primarily in emerging economies (Dulca 2013). To put this in perspective, this would be a 60 % increase in the combined length of all road and railway networks around the world (*ibid.*). These predictions are accompanied by an expected upward trend in oil consumption in 2035, driven primarily by demand in China and India, with oil consumption declining in Organisation for Economic Co-operation and Development (OECD) countries (IEA 2013b).

The demands for higher levels of mobility and infrastructure expansion reflect that transportation delivers beneficial and often essential services to local as well as global economies. In many areas of the world, investing in better transportation

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<sup>1</sup> For example, see Replogle (1991), Black (1996, 2010), Gudmundsson and Hojer (1996), Button and Nijkamp (1997), UKRTSD (1996), Greene and Wegener (1997), Whitelegg (1997), Black and Nijkamp (2002), Hoogma et al. (2002), Steg and Gifford (2005), RAE (2005), Banister (2005), Hall (2006), Barrella et al. (2010), Amekudzi et al. (2011), Zietsman et al. (2011), Holden et al. (2013), and Booz Allen Hamilton (2014).

systems to move people and freight is seen as one of the most effective ways to improve economic well-being and performance.<sup>2</sup> However, the negative impacts of adding additional passengers and traffic to existing transportation systems and/or expanding these systems could begin to undermine the benefits realized from this growth. The key focus of most existing methods used for transportation planning and decision-making is to quantify the net balance of economic benefits. We argue in this book that there is a pressing need to expand the scope and scale of transportation decision support to encompass the full vision of sustainable development of which net present economic benefits are only one element.

In terms of the negative impacts of transportation, the sector's reliance on oil has long been a major indicator of its unsustainability, although some modest inroads in reducing fuel consumption are beginning to be made through the sale of hybrid, plug-in hybrid, and all-electric vehicles. In 2011, the concentration of carbon dioxide in the atmosphere reached 391 ppm (parts per million), an increase of 40 % above pre-industrial levels and close to the 400 ppm level that is predicted to increase the Earth's global average surface temperature by 2 °C (3.6 °F) (IPCC 2013). That same year, over 31,000 million tonnes of CO<sub>2</sub> were emitted from fuel combustion, 22 % of which came from the transportation sector, with 17 % attributed to road transportation (IEA 2013a). Similarly, transportation also remains a major contributor to the emissions of other air pollutants including diesel particulate matter, hydrocarbons, and oxides of nitrogen. Within the context of increasing global demand for transportation infrastructure and services, the transportation sector will come under growing scrutiny as efforts to address climate change and other global and national environmental concerns intensify.

Beyond climate change, the transportation sector is also responsible for a wide range of impacts that affect ecosystem integrity and biological diversity and directly affect human health and well-being. The growing field of "road ecology" provides a good example of the concerns that researchers (across a wide range of disciplines) have with the physical, chemical, and noise impacts of the road network and traffic on vegetation, wildlife, aquatic systems, etc. (Forman et al. 2003; van der Ree et al. 2011). In terms of human health, mobile source air toxics—such as benzene, 1,3-butadiene, formaldehyde, acetaldehyde, acrolein, polycyclic organic matter (POM), naphthalene, and diesel particulate matter—remain closely monitored and regulated due to the potential health risks they pose (Carr et al. 2007; Shrouds 2009; Milojevic et al. 2014). It is estimated that road traffic accidents typically cost between 1 and 2 % of GDP for both developed and developing countries (WHO 2004, 2013). The total global cost of accidents was estimated in 2000 to be almost US\$518 billion per year. Finally, the design and layout of transportation infrastructure can directly shape the livability and quality of neighborhoods (Wheeler 2013).

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<sup>2</sup>This is especially the case in emerging economies where the development of rural roads is considered to be essential for connectivity and economic development (Faiz 2012).



As transportation systems continue to develop and expand across the world, these types of environmental and social impacts are likely to remain or in some cases, such as climate change, become an increasingly important driver of the need for sustainable development. At the 2012 Rio+20 conference, the subject of sustainable transportation was highlighted as central to sustainable development (UN 2012), and many nations, regions (such as the European Union<sup>3</sup>), and multi-lateral development banks are responding to this call for action—see, for example, the “Commitment to Sustainable Transport” made by eight development banks (AfDB et al. 2012, 2013). Such activities are increasing the global demand for professionals who are well-equipped to manage the transition toward more sustainable transportation systems.

The science (and social science) of understanding sustainable development issues is well documented and continues to evolve (Black 2010; Cox 2010; Alonso et al. 2015). This has been matched by neither progress in policy making nor in how to approach policy making to tackle such cross-cutting problems. A goal of this book, therefore, is to provide, through theory and case study analysis, some generic principles to advance the capability of the transportation profession to promote sustainable development, while the debate on what this means in different contexts continues to unfold. It also asks questions that highlight the types of research that academics might do to improve decision-support tools and techniques.

This book focuses on the role that indicators and performance measurement frameworks (or systems) have in making sustainability count for decision-makers, planners, operators, and other stakeholders within and beyond the field of transportation. It does so because “what is measured is what matters.” This often used statement hides some very important yet under-discussed issues relating to the politics and practice of decision-making. What gets measured and how it gets used are part of the political process. The information which is considered to be important in a debate and how it is interpreted is a reflection of the framing of the problems to be tackled by government and nongovernmental actors. This means that, far from being about what to measure and how, this book addresses more fundamental questions about how the different actors in the transportation system see their role in the broader sustainable development debate. This is discussed further in Chap. 5.

For sustainability to matter, the concept needs to be made a priority and then effectively operationalized in our decision-making frameworks. Once this occurs, what is measured will also matter for sustainability. In the next four chapters of the book, attention is given to clearly describe sustainable development and sustainable transportation and to draw a boundary around the transportation system and its governance to which these concepts are applied. This provides a critical baseline position to understand and argue for the application of sustainability procedures to improve decision support.

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<sup>3</sup> See the European Union’s efforts to promote Sustainable Urban Transport Plans, [http://ec.europa.eu/environment/urban/urban\\_transport.htm](http://ec.europa.eu/environment/urban/urban_transport.htm) (accessed 6/2/2014).

Sustainability is a complex and multidimensional issue that we argue cannot be made operational without the use of indicators. Since the term “indicator” has different meanings across multiple disciplines (such as engineering, law, finance, and policy), a consistent definition of an indicator is provided (in Chap. 6) and applied throughout the book. While there is a growing body of literature on sustainable transportation indicators—for example, see Bongardt et al. (2011), Holden (2013), Holden et al. (2013), Jeon et al. (2013), and Zietsman et al. (2011)—we argue that there is no “predefined” set of indicators that can be applied to measure the performance of sustainable transportation policies or programs. What works in one place cannot simply be taken and reapplied elsewhere. Predefined sets of sustainable transportation indicators can be informative, but they should not be accepted wholesale, without consideration to the political, organizational, and economic environment in which they are being applied.

During the preparation of this book, the authors supported a National Cooperative Highway Research Program (NCHRP) research project to develop NCHRP Report 708, “Guidebook for Sustainability Performance Measurement for Transportation Agencies” (Zietsman et al. 2011). This project led to the identification of hundreds of potential transportation indicators that could be used within a sustainable transportation performance measurement system.<sup>4</sup> The research also supported a number of interactive practitioner workshops to test the application of the performance measurement framework developed by the research team. These workshops revealed how an individual’s or group’s *perspective* plays a critical role in shaping which indicators were selected for what purpose. For example, a group of planners from a transportation agency might be interested in using indicators to *describe* a perceived problem or *communicate* progress that has been made on addressing a problem. The indicators selected for each type of application may be quite different. The same indicator may also be selected, but it could be viewed quite differently due to the *framework* through which the indicator is viewed (see Chap. 7). As a result of this experience, and from supporting research undertaken in the EU (Journard and Gudmundsson 2010), the importance of clearly specifying the context in which indicators are “applied” became apparent. Every institution operates at a different scale, with a different purpose, and to a different set of stakeholders. This context-specific nature of indicator application means that it is not possible (or perhaps wise) to provide a single set of metrics that will be applicable across different transportation agencies. It is instead necessary to focus on how indicators can support the alignment of purpose to sustainability goals across the system. While we do not dispute the value of standardizing indicators for comparative purposes, our focus is on the development of performance measurement systems that are fine-tuned to the specific needs of a transportation entity wherever they sit in the system.

The real-world dynamic environment in which indicators are applied is probably one reason why there has been limited progress in realizing more sustainable forms

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<sup>4</sup>These indicators are provided as an appendix to the main NCHRP report.

of transportation. As will be discussed in this book, and highlighted by several of the case studies, the implementation of an effective sustainable transportation performance measurement system is a significant undertaking that requires leadership and a sustained effort, along with space and time to adapt the framework as learning occurs. In this book, we deliberately stopped short of presenting an idealized performance measurement framework, since we recognize the importance and persistence of existing decision-making practice and the need to make sustainable transportation work within existing governance structures. This is not to say we are content with the status quo. Rather, it is a recognition that institutions change slowly and therefore we need to start the task now, demonstrate that planning for sustainable transportation leads to better decisions and outcomes, and work to transform systems over time.

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## 1.1 The Structure of the Book

This book is structured into two distinct parts which are preceded by this introduction (Chap. 1) and followed by our concluding remarks in Chap. 12.

### Part I—Conceptual Foundations

- Chapter 2: Sustainable Development
- Chapter 3: Planning for Transportation
- Chapter 4: Transportation and Sustainability
- Chapter 5: Governance and Decision-Making in Transportation
- Chapter 6: Indicators
- Chapter 7: Frameworks

### Part II—Case Studies

- Chapter 8: European Union Transport White Paper
- Chapter 9: High Speed Rail in England
- Chapter 10: New York’s GreenLITES Rating Systems
- Chapter 11: Japan’s “Eco-City Model” Program

Part I of the book develops several conceptual foundations on which the remainder of the book rests. It begins by exploring the emergence of the concept of sustainable development through the lens of key international conferences and publications (Chap. 2). By tracking the historical evolution of the concept, the compromises that were made when crafting key foundational texts such as *Our Common Future* and the Rio Declaration are revealed. One of the main objectives of the chapter is to clarify the type of development that is being promoted or endorsed when the Brundtland formulation of sustainable development is invoked. Since most efforts to promote sustainable transportation are linked with the Brundtland definition, having a clear grasp of the strengths and weaknesses of

this definition is important. Chapter 2 also outlines the “weak” and “strong” forms of sustainability to create a continuum along which sustainable transportation initiatives and programs could be placed. Weak sustainability can be described as an environmentally oriented business-as-usual approach to development, whereas strong sustainability is a more radical reformulation where human activity has to be kept within macroecological limits. Regardless of one’s perspective on sustainable development, it is helpful to be able to articulate how policies and initiatives designed to promote sustainable transportation align with established theoretical frameworks. Knowing where, in principle, an organization stands on the weak to strong sustainability continuum is likely to promote learning and a deeper appreciation for what is or is not likely to be achieved through the organization’s actions. Chapter 2 concludes by highlighting the need to adopt a holistic and integrative perspective to the design of policies, programs, or initiatives targeted at addressing unsustainability.

Having established a common understanding of sustainable development, Chap. 3 provides a comprehensive definition of a transportation system and attempts to draw a boundary around what we mean by “transportation.” In particular, it considers how the components of the different transportation modes and networks fit together and are organized within a societal and environmental context. This broad description of a complex socio-technical system highlights the connections that exist between societal demand for travel and the consequences of this travel on communities and the natural environment. The chapter also discusses how the transportation system is continually shaped by political-economic actors/stakeholders, as well as the availability of financial resources and the capacity to develop/deliver transportation services—topics explored in more depth in Chap. 5.

In Chap. 4, we revisit the material introduced in Chap. 2 through the lens of transportation. The chapter follows the evolution of the definitions and principles of sustainable transportation since the early 1990s and argues that the current focus on the concept might be too narrow and constraining. By positioning the transportation system as one of many systems (or sectors) contributing to development, a holistic perspective is presented that considers the transportation system through the lens of sustainable development. Thus, the transportation system is conceived as one of several interconnected systems, which raises the importance of developing integrated, multi-sectoral solutions to the sustainability challenges ahead.

Having defined sustainable development and sustainable transportation and drawn a boundary around what we consider to be a transportation system, Chap. 5 explores the governance of this system. In particular, the chapter discusses how the transportation system is governed by a range of state and non-state actors that operate at the local to national/international level. The chapter makes the case for the state’s intervention in shaping the transportation system—acknowledging that this task in itself is a highly complex endeavor—and argues for the coordination (or better still, integration) of policy within any given level of government to promote sustainable development/transportation. Several characteristics of governance systems that are considered to promote planning for sustainable transportation are also discussed. Finally, the chapter defines two broad domains of the