1. Introduction to *Innovations in Transport*

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**TRANSPORT INNOVATIONS AND IMPACTS ON SOCIETY**

Innovations induce important societal changes, in general, and also in the transport system. In this book we define transport innovations as ‘new elements of the transport system that are implemented in the real world’. In other words, a new element that has not been implemented yet is not presently an innovation, but a potential or candidate innovation. We define the transport system as ‘the comprehensive system of infrastructures, vehicles, fuels/energy supply, services, prices, travel times and effort to move people or goods’. We label infrastructures, vehicles, fuels/energy supply, and services as the main components of the transport system. ‘Effort’ includes all components relevant for the resistance of travelling, additional to travel time and travel costs. It includes factors like perceived safety, mental and physical effort, and the (dis)joy of travelling by various modes of transport. Consequently, transport innovations can include all those main components of the transport system, as well as their mutual interactions. And innovations can be a completely new form of infrastructure, vehicle or energy supply, or completely new services, but also a part of one of these components. For example, we consider the high-speed train as an innovation that is part of the rail system. And we consider the electric vehicle as an innovation within the car system. Websites that allow for the online comparison of airline tickets are also innovations, coming within the overall category of information provision and ticketing.

In some places in this book a distinction is made between radical and incremental innovations. It is not straightforward to assign innovations to either of these two categories. Take the introduction of the three-way catalytic converter to cars in the 1980s as an example. This technology did not have an impact on the functional characteristics of cars, so from the perspective of the car as a mode of transport it can be seen as an incremental innovation. But from the
Innovations in transport perspective of the exhaust system of cars it certainly is a radical innovation because, unlike exhaust systems without a three-way catalytic converter, it does (strongly) reduce exhaust emissions, and it changed the motor management system, replacing carburettors with injection systems. In addition, it requires unleaded petrol, inducing fuel changes. So, the distinction between radical and incremental innovations depends on the perspective one takes with respect to innovations.

Important examples of transport infrastructure innovations implemented in the past are motorways, rail, high-speed rail, maglev rail, modern airports, and cycle lanes. In the category of vehicles, examples are all vehicle types (cars, trains, bikes, …) as well as major changes within these vehicle types, such as e-bikes, or electric cars. The introduction of liquefied natural gas (LNG) and unleaded petrol, as well as electric cars, are examples of fuel/energy innovations.

The fact that we mention the electric car as both a vehicle- and an energy-related innovation makes clear that some innovations combine multiple components of the transport system. In the case of electrical vehicles, the component of infrastructure is also included: electric cars need charging infrastructure.

In the area of services, innovations include shared bikes and cars, smart cards for public transport, and mobility as a service (MaaS). Innovations in the area of ticketing and information are important service innovations: nowadays it is much easier to find timetables of public transport and airline services, and book tickets, than a few decades ago.

In the area of goods transport, the container is a radical innovation, allowing for the combination of many product types and shippers on one vessel, and reducing barriers for multimodal goods transport (van Ham and Rijsenbrij, 2012; Lau et al., 2013).

The concept of transport innovations is strongly related to time and place: it is important where and when new elements are introduced. For example, building cycle lanes in a city without any bike infrastructure is an innovation for that city, whereas it is not in cities with a long cycling tradition.

Transport innovations implemented during the past two hundred years had many wider impacts on societies, as well as dramatically changing the transport system. Improved transport systems made the implementation of complex supply chains possible, leading to relocations of production in its various stages. And improved transport systems fuelled urban sprawl, just to mention a couple of important societal changes. A part of these changes is that transport has become much less expensive over the past centuries (Filarski and Mom, 2008), which has contributed to increasing welfare levels. The changes in the transport system made it possible for people to reach many more destinations, extending their activity spaces dramatically. The theory of constant travel time
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Budgets illustrate that over a large group of people, such as all inhabitants of a country or state, the average time spent travelling is quite stable at around 60 to 75 minutes per person per day (e.g. Mokhtarian and Chen, 2004). Therefore, innovations that made transport faster made people travel further within roughly the same time, resulting in important accessibility gains (but also higher environmental impacts).

SUCCESS OR FAILURE OF POTENTIAL TRANSPORT INNOVATIONS, AND SOCIETAL IMPACTS OF TRANSPORT INNOVATIONS

Looking at the past two centuries, we can conclude that the transport system is changing constantly. So the transport system will very likely also change in the future. But it is difficult to accurately forecast which potential innovations might be successfully implemented in the future and what the impacts of these implementations on societies might be. It is also very difficult to estimate the importance of public policies, and the research and development of companies, for the success or failure of potential innovations, as well as their societal impacts. Should policy makers and planners develop policies and plans for new potential innovations or not? If so, which? Should they, for example, plan new infrastructure for e-bikes, or for the Hyperloop? If so, where and when? Should they adapt cities to accommodate automated vehicles? Should they reduce parking spaces in residential areas to be built, because people might increasingly share cars? For companies it is very difficult to accurately forecast the return on R&D investments in general, including in the area of transport innovations. This applies even more to radical innovations (as opposed to incremental ones): the list of failed potential transport innovations is much longer than the list of successfully implemented transport innovations (Filarski and Mom, 2008). So, activities in the area of innovations, both for companies and for policy makers, are often in the category of ‘high risk, high gain’. Many companies need innovations to survive in the longer term, so they need to take onboard the high risk of related R&D investments. And policy makers know that the transport system will change in the next hundred years, but not clearly how. In other words, uncertainties are very large, leading to investments that are high risk in terms of time and money, but if successful, transport innovations might significantly change the transport system and society.

AIM AND SCOPE OF THIS BOOK

We are not under the illusion that we can greatly reduce those uncertainties. But in producing this book we do have the ambition to be helpful in dealing with those uncertainties.
More specifically, this book aims to help understand the success or failure of potential transport innovations, as well as their societal impacts.

Here we define ‘success’ as the real-world implementation of potential innovations. We realize this is a simplistic definition of success – innovations might be implemented, but we might regret this implementation with hindsight because the disadvantages outweigh the advantages of the real-world innovations. We argue that another definition of success in this case could be that potential innovations not only need to be implemented in the real world but they also need to have net benefits. We do not dig into the evaluation of all pros and cons; this is beyond the scope of this book.

We put the topic of transport innovations into the context of (changing) societies. What works in one context does not necessarily work equally in another. For example, rail infrastructure might serve high-income groups in one country, increasing inequalities, and low-income groups in another country, reducing inequalities. And societies are constantly changing, examples of important changes being digitalization, population decline or growth, increasing focus on sustainability, the aging population and globalization. All these changes can have important impacts on the transport system in general, as well as on the success or failure and societal implications of potential transport innovations.

The book is limited to complex innovations in which both public and private actors are involved. Without being able to draw a sharp line – it can be difficult to say beforehand what the role of different actor types in the real-world implementation of potential innovations might be – we can give some examples. Further implementation of MaaS or hydrogen cars, and hydrogen airplanes and the Hyperloop, typically will never happen without the involvement of public and private actors, but a new ticketing platform for airline tickets probably can be implemented without public involvement.

To reach our aims we combine the insights from several disciplines. Innovation and transportation sciences provide the most important theoretical underpinnings. It is important to realize that innovation sciences combine and integrate several other disciplines, such as evolutionary economics, business economics, managerial sciences, psychology and history.

The target audience for this book includes academics in the area of transport innovations at the strategic level, students, companies in the area of transport innovations, policy makers and planners.

Part I of the book introduces several frameworks that help to understand the success or failure of potential innovations in general, as well as societal implications. Part II then discusses several potential transport innovations, partly making use of the insights of Part I.
POLICIES RELEVANT FOR INNOVATIONS

Before we continue with Part I, we will explain the role of public policies, because of the focus of this book on complex public–private innovations. Table 1.1 shows the dominant relationships between policy instruments and technological and service innovations. In addition, it shows how these instruments can influence other determinants for the impact of the transport system on the environment, safety and accessibility. These determinants indirectly are relevant for the effect of policy instruments on innovations, as we will explain below.

Table 1.1 shows that in general (not limited to policies relevant for innovations) policy makers have multiple categories of instruments available, a first category being regulations. Emissions and safety standards for vehicles and maximum speeds on roads are important examples. A second type of policy instrument concerns prices, such as levies on fuel or subsidies on public transport. Next, via land-use planning they can influence travel behaviour, example policies being those that influence densities, the degree of mixing of land uses, and distances between public transport access points and residential, work and other areas (e.g. Ewing and Cervero, 2010). The fourth category encompasses infrastructure policies, mainly those pertaining to building and maintaining roads, railways, ports, airports, canals and other infrastructures. Next, many policy makers develop specific public transport policies, in addition to the four policy categories above, such as defining routes and service levels for public transport services and rules for tendering public transport services. Via marketing, information and communication they can indirectly (try to) influence the behaviour of travellers and other actors, such as public transport companies. As Table 1.1 makes clear, these policy types can be used to stimulate or discourage innovations, and to change transport volumes (expressed by the number of passenger kilometres or the number of trips), modal split (volumes split by travel mode – in the case of passenger transport: aircraft, car, public transport, bike, motorized two-wheelers, and other; in the case of goods transport: shipping, barge, lorry, train, air), the efficiency of using vehicles (expressed in load factors in the case of goods transport and vehicle occupancy rates in the case of passenger transport), and the way of using vehicles (speeds, acceleration, braking). It is beyond the aim of this chapter to explain all the instruments in detail. We limit ourselves to the options to use policy instruments to stimulate or discourage innovations.

Not all these policies are important from the perspective of innovation. Table 1.1 shows that regulations, prices, infrastructure and public transport policies can be used to stimulate or discourage innovations, both technological and service innovations. To illustrate we give some examples. Via regulations
### Table 1.1 Dominant relationships between policy instruments, innovations and determinants for the impact of transport on the environment, safety and accessibility

<table>
<thead>
<tr>
<th>Policy instruments</th>
<th>Technological innovations</th>
<th>Service innovations</th>
<th>Transport volume</th>
<th>Modal split</th>
<th>Efficiency of using vehicles</th>
<th>Driving behaviour</th>
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<td>Infrastructure</td>
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<td>Marketing, information and communication</td>
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*Source: Updated from van Wee (2009).*
policy makers can allow or forbid innovative technologies, such as hydrogen cars, private small aircraft or electric scooters. Or they can require innovative services like ticketing, information and payment services for public transport. Next, they can stimulate or discourage technical and service innovations via price instruments. They could give tax benefits or subsidies to innovations they want to support, and put levies on innovations they do not want. An example of the latter category is (higher) taxes on vehicle types they prefer to not be sold frequently, for environmental or safety reasons. They can subsidize information provision services for public transport that cannot survive on a commercial basis only. Infrastructure policies could be the decision to build innovative infrastructure types, such as high-speed rail lines, charging infrastructure for electric vehicles, or maybe maglev rail or Hyperloop infrastructure in the future. Once these infrastructures are in place, services using them will be offered. Through specific public transport policies, such as tendering procedures, policy makers can force or stimulate public transport service providers to use innovative technologies like electric buses or implement innovations in information and ticketing services.

THE CHAPTERS IN THIS BOOK

We finally give a brief overview of the chapters in this book.

Part I  Frameworks for Analysing Transport Innovations

Part I looks at frameworks for analysing innovation in transport. It does not attempt to be comprehensive, but considers the state of the art in innovation theories applied to sustainable transport, with an emphasis on approaches to understanding behaviour and an example of current modelling ideas.

In Chapter 2 Pel discusses the use of transitions theory in transport innovation. The author considers moving from ecological modernization to ‘system innovation’, from optimization to experimentalism, from sustainable technologies to socio-cultural transformation and from innovation to exnovation (the decline of established systems and technologies). He shows how transitions theory puts innovation success, failure and societal impacts in a broader perspective, and how it takes the pursuit of ‘sustainable’ transport innovation well beyond the development of clean technologies.

Chapter 3 written by Zenezini and Tavasszy provides an example of how current developments in transport modelling in the use of an agent-based modelling (ABM) approach can be used to analyse micro-level decisions and behaviour. The authors address the reorganization of logistics processes, usually neglected in innovation studies of transport, by representing transport
Innovations in transport systems as business ecosystems. They introduce a new ABM framework for freight transport innovations that helps to fill this gap.

In Chapter 4 Rau and Scheiner review the use of travel biographies. Investigations of mobility biographies in various disciplines and in interdisciplinary collaborations have cast new light on changes in how people travel that relate to specific life events and phases. Recent innovations in mobility biographies research (MBR) add that individuals cannot make autonomous choices but that their decisions are embedded in complex contextual conditions. Practice-theoretical approaches imply that wider material and social conditions (including transport innovations) represent constitutive elements of practices in transport behaviours. Taking individuals’ and policy stakeholders’ subjective representations of transport issues seriously (as opposed to simply relying on ‘matters of fact’) is another approach that may help to identify opportunities for change. MBR contributes to creating such knowledge by studying stability and change in mobility over the life course.

Research has shown that travel behaviour can be influenced by economic and social nudges. In Chapter 5 Riggs explores how individuals’ decisions are framed by the built environment as well as by behavioural factors. It explores how transportation nudges constitute a growth area for transportation planners and engineers, particularly as travel choices and trip complexity increase with smart, connected and automated mobility services.

In Chapter 6 Annema reviews theories of innovation applied to transport. The theories considered are (1) the opportunity vacuum as a conceptual model for the explanation of innovation, (2) the technological innovation systems (TIS) approach, (3) the political economy of transport innovations, (4) the multi-level perspective (MLP) on transitions, (5) Rogers’s theory on diffusion of innovations, (6) the hype cycle and (7) theories and frameworks that aim to explain the role of industries in innovations. Modern innovation theories – broadly speaking – reject the idea of the possibility of an easy innovation fix. Innovations in transport involve many actors with large and opposite interests. Theories can provide the basis for policy development and innovation management. They can help to understand the social and technical processes of innovation in transport. They can help to understand which factors could positively contribute to the success of a specific innovation. They can also help to understand time and place in innovation adoption.

Part II Transport Innovations

Part II first presents three chapters on technological innovations that are already partly implemented: vehicle electrification, e-bikes, and light electric vehicles in city logistics. In Chapter 7, Langeland, George and Figenbaum discuss the case of vehicle electrification in Norway. Norway is a very inter-
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esting case when it comes to vehicle electrification because of its worldwide leading position with respect to the market penetration of battery electric vehicles. The authors evaluate how suitable the technological innovation systems (TIS) framework is for understanding emerging technologies such as battery electric vehicles (BEVs) and fuel cell electric vehicles (FCEVs). The content of the chapter in that respect cuts across the themes of Parts I and II as it introduces and evaluates the TIS framework while also using BEVs and FCEVs as a case study.

Sun, in Chapter 8, then elaborates on the success and failure plus impacts of the e-bike. Departing from the transitions theory perspective of Pel (Chapter 2) and other theories partly presented in Chapter 6 by Annema, Sun explains why this transport innovation has gained a high level of popularity. An important conclusion is that environmental and social impacts to a large extent depend on the impacts of e-bikes on travel behaviour, including substitution between modes. These impacts are discussed making use of the mobility biographies approach as presented by Rau and Scheiner in Chapter 4 of this book.

In Chapter 9 van Duin, Ploos van Amstel and Quak next focus on light electric vehicles for city logistics, making use of the TIS framework of Langeland, George and Figuenbaum presented in Chapter 7. Because the framework didn’t provide them explicit insight as to whether the factors presented in the TIS framework are success or failure factors, strengths or weaknesses, opportunities or threats, they suggest an additional framework to find strategies for how to proceed with the outcomes of the TIS framework by categorizing them as strengths, weaknesses, opportunities and threats.

In Chapter 10 Snelder, Homem de Almeida Correia and van Arem discuss automated driving, an innovation that at the time of writing this book (2022) has been partly implemented but is only in its early stages. Fully automated driving is a candidate innovation. The authors discuss the possible or likely first-order (travel related), second-order (vehicles, land use and location choices, and infrastructure), and third-order (societal relevant effects, mainly environmental and safety effects) implications and how these relate to success or failure of future developments of automated driving. They conclude that the future of (higher levels of) automated driving is quite uncertain, and that this future depends on related fundamental challenges with respect to human factors, technology, infrastructure and legislation.

After these more hardware-related innovations, chapters 11 to 13 focus on service innovations: carsharing, MaaS and e-shopping. In Chapter 11 Münzel, Arentshorst, Boon and Frenken explain the success and failure plus societally relevant impacts of carsharing. Based on interviews with stakeholders they conclude that stakeholders agree on the importance of developing visions for the future transportation system of which carsharing is an integral part, setting up an information campaign, and implementing measures supporting carshar-
ing in municipalities. Controversial issues include the sharing of data among industry providers, collaboration for setting up an aggregated overarching booking platform, and changes in the national taxation of car ownership. The results show that measures supporting the carsharing niche to grow incrementally are evaluated as feasible and desirable while more disruptive, potentially higher-impact measures changing the car ownership regime are less popular across the consulted stakeholder groups.

In Chapter 12 Veeneman focuses on mobility as a service (MaaS), a service innovation that has received a lot of attention from researchers and policy makers during the past five years or so. He departs from the transitions theory perspective of Pel (Chapter 2). Making use of real-world cases he shows how MaaS developed (1) from a specific service to help travellers deal with a fragmented landscape of mobility towards an incremental system innovation, (2) from a singular private innovation to be implemented to an intricate effort from both governmental and private entities, (3) from a new additional service to a rethink of governance, and (4) from a system improvement to a system innovation.

In Chapter 13 Shi, Cheng and Witlox discuss e-shopping, including the relationships between e-shopping and travel behaviour. Departing from the multi-level perspective of Geels (2011) (see also Chapter 6 by Annema in this book), they provide a conceptual framework to understand the emergence and growth of e-shopping and then consolidate the existing literature to analyse in particular its transport and social implications and associations with the built environment.

Next, in Chapter 14, Araghi and Wilmink elaborate on the success or failure and impacts of a candidate innovation that potentially could be implemented in the more distant future, after 2030: the Hyperloop. The content of this chapter, like that of the chapter by Langeland, George and Figenbaum, cuts across the themes of Parts I and II of this book, because it starts with the notion that the Hyperloop is a disruptive innovation, and a framework for such innovations is lacking. The authors therefore first develop a conceptual disruptive innovation framework, setting off from the disruptive innovations theory of Christensen et al. (2015; 2018). They conclude that it is unlikely that the Hyperloop will be disruptive in the short term (i.e. the coming decade), but that the need to reduce the carbon footprint of the transport sector and possible breakthroughs in reducing the infrastructure expenses (and subsequently travel costs) of the Hyperloop may be helpful for its realization and the potential disruption of the transport sector.

Finally, in Chapter 15, Craens, Frenken and Meelen take a completely different angle: they depart from a mission-oriented innovation policy. A key difference between this chapter and the other chapters in Part II of this book is that no specific innovation is the centre of attention, but rather a mission
of policy makers, in this case the Swedish ‘Vision Zero’ approach to traffic safety, aiming to greatly improve road safety. They explain what the Vision Zero policy entails, how stakeholders dealt with ‘transformational failures’, and what made the policy a success. They end with lessons for the development of new mission-oriented innovation policies to address societal challenges.

After reading all the chapters it becomes clear that several in Part II make use of theories and frameworks presented in Part I. But the links between both parts are not very strong, one reason being that Part I unavoidably presents only a selection of relevant frameworks. There are many more, and the authors of the chapters of Part II were free to choose the theoretical underpinnings for their chapter without being limited to the frameworks presented in Part I. Another reason is that some chapters do not set off from an existing innovations framework at all, but rather take a more pragmatic stance to discuss the innovations at stake.

Unavoidably this book only discusses some of the more important examples of transport innovations, and there are many more that could play a substantial role in the future, examples being drone deliveries, hydrogen aircraft, e-fuels, non-road vehicle automation, mobility hubs and shared taxis. So this book is not aimed to be a handbook providing all the important theories available to help understand complex public–private innovations, nor one that discusses all dominant (candidate) transport innovations. Rather, it is meant to be a source of inspiration to help understand the success or failure of complex public–private (candidate) transport innovations and their societal impacts.

Because students studying complex public–private innovations in the transport system are a very important category of users of our book, we end with some reflections on how students can best use this book. Firstly, in searching for theories and theoretical frameworks students are encouraged to not only read the theoretical chapters of Part I plus a few additional theoretical contributions presented in Part II. There are many more theories and theoretical frameworks that can be useful to understand the success or failure and the impacts of innovations. Two of us have been teaching these topics to master’s students at Delft University of Technology for many years, and students were able to find many more theories and frameworks. Secondly, we encourage students to study the innovations presented in Part II from the perspective of theories other than those presented in this book, which may result in gaining additional insights. Finally, and most importantly, we hope this book encourages students to study innovations other than those presented in Part II, and we hope they are inspired by the chapters presented in this book.
REFERENCES


