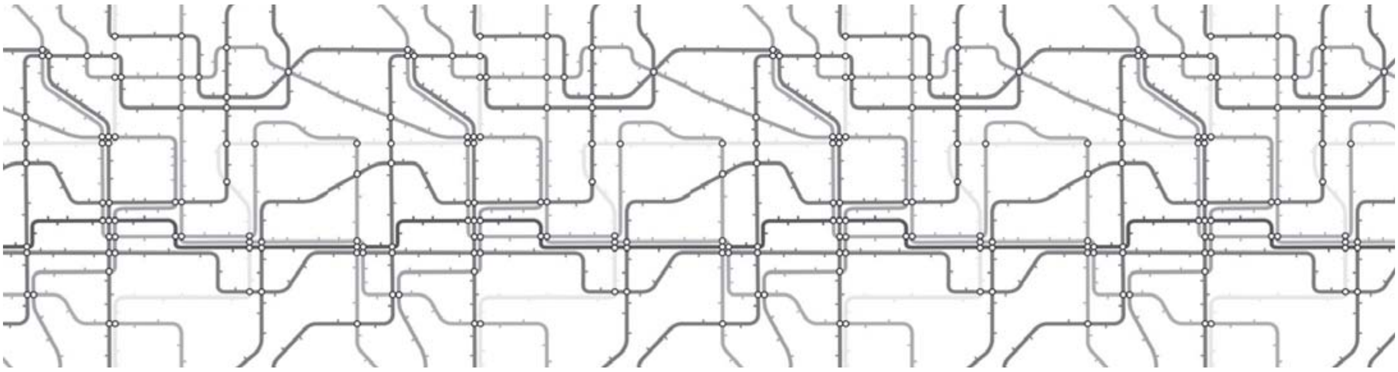
The SAGE Handbook of

Transport Studies



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Introduction

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TRANSPORTATION: A SCIENCE OR A FIELD OF APPLICATION?

This book is about transportation. It is common to state that transportation is not a science but a field of application. While such a statement may give the impression that transportation is not an endeavor serious enough to require its own formal discipline, the reality is rather the opposite. Transportation is so complex, multifaceted and extensive that no single scientific discipline would be able to encompass its role, functions and operations. Trying to define a science of transportation would probably end up being counterproductive, as it would seek to provide finality to a field that is constantly evolving as economic, technological and social conditions change.

The multidisciplinary character of transportation can be seen as both a weakness and as a strength. It is a weakness in the sense that it is unlikely that a consensus will ever be reached, outside generalities, about what transportation truly involves as a field of investigation. Different issues arise as important depending on whether one looks at transportation from an engineering, economic, operations research, sociological, environmental or geographical standpoint. For an engineer, transportation is composed of modes and infrastructure, from road pavement to container cranes. This infrastructure must be built, operated and maintained. For an economist, transportation could relate to commercial opportunities and the impacts of transport costs on flows and the price of products and services. For a sociologist, transportation could relate to mobility levels according to income, gender and socioeconomic status. Indeed, the now well established "mobilities paradigm" in the social sciences demonstrates the very wide range of sociocultural concerns now commonly researched in the field of transportation (see Cresswell, 2006; Sheller and Urry, 2006; and the *Handbook of Mobilities* edited by Adey et al., 2013).

Transportation studies' multidisciplinarity is also a strength in that it has conveyed a long tradition of using perspectives and methodologies borrowed from various disciplines where they are relevant and useful. Pragmatism often prevails in transportation as the goal is commonly to improve the capacity and performance of various transportation systems such as highways, transit systems, maritime shipping and logistics. Conflicts of ideology are less common, although by no means absent; the field of transport policy can be subject to controversy around issues such as modal choice and approach, type of ownership, regulation level, governance, investment priorities and level of expected impact.

Nevertheless, from this range of perspectives and methodologies we can identify a series of elements, characteristics and methods that might be regarded as core to transport studies. Our aim is not to provide a detailed exposition of each of these, but rather to introduce them as a framework to help understand the themes that develop in relation to the various *transport systems* described and explained throughout the book.

What are transport systems?

In the context that the fields of application in transport studies cannot be effectively reconciled under some "unifying theory", a good start is to consider transportation as a system. This immediately implies complexity and interrelations between different elements, and three such elements are:

- *Transportation nodes*. Transportation primarily links locations, often referred to as nodes. They serve as access points to a transport system or as transshipment/intermediary locations within a transport network. This function is mainly serviced by transport terminals where flows originate, end or are being transshipped from one mode to another.
- *Transportation networks*. This relates to the spatial structure and organization of transport infrastructures and terminals supporting and shaping movements.
- *Transportation demand*. This considers the demand for transport services as well as the modes used to support movements. Once this demand is realized, it is expressed as interactions that flow through a transport network.

It is instructive to note here a number of conceptual characteristics of transport systems and their inter-related elements drawn from complexity science, as recognized by the OECD (2009). Key among these are:

- *Adaptability*. This is a standard characteristic that is best reflected by the concept of competition where transport firms adapt to their competitors and to other socioeconomic changes (which lead to changes in demand).
- *Self-organization*. Individuals' choice of modes and routing within a transport network is the outcome of the consideration of all the respective advantages/disadvantages of modes and terminals. Supply chain management is also illustrative of self-organization as sourcing and distribution strategies change to reflect complex changes in input and distribution costs.
- *Non-linearity*. This refers to the fact that transport systems' operation is not stable and uniform but subject to sudden perturbations. These in turn may be thought of as rhythmic or non-rhythmic. Peak hour congestion on a road or railway system is a good example of a rhythmic non-linear characteristic, as it is reasonably predictable but each degree of additional congestion results in exponential delays. Non-rhythmic disruptions, such as a serious road accident or the shutting down of an airport hub because of a snow storm or a volcanic eruption, will trigger significant but potentially unexpected disruptions through the whole network. Transport systems thus need to be designed with issues of capacity and resilience firmly in mind.
- *Attractors*. These represent the stable components of the transport system that have a long-term influence on the nature and extent of both the system itself and the flows within. Land use is a particularly stable component of spatial interactions since its characteristics are slow to change. The same applies to transport terminals that are long-term locations in the convergence of flows.
- *Phase transition*. Although a considerable degree of long-term stability in any given transport system may be expected, certain developments or tipping points may trigger notable changes in its properties. Technological (or technical) innovations have in the past involved paradigm shifts

for transportation systems – for instance, containerization generated entirely new flow patterns, modes and terminals, as did the advent of commercial aviation – but other issues such as those related to peak oil are also likely to be highly significant in triggering a phase transition in 21st century transport systems. Phase transitions are themselves non-linear and can often be system-specific, although this is not to say that 'spillover' effects will not be observable, such as the impact of fast-moving information and communications technology development on the operation of automobile and public transport systems.

How do we study transport systems?

Transportation planning and analysis are interdisciplinary by nature, involving among others, civil engineers, economists, urban planners and geographers. Each discipline has developed methodologies dealing with its respective array of problems. Because transportation is an infrastructure-intensive activity, engineering has been the dominant approach to transportation studies, but any number of issues from globalization, through the setting of extended supply chains, to economic development and social exclusion require methods related to management science, operations research, economics and finance, sociology and anthropology as well as from other perspectives. Two common traits of transportation studies, regardless of disciplinary affiliation, are a heavy reliance on empirical data and the intensive use of data analytic techniques, ranging from simple descriptive measures to more complex modeling structures.

Transportation studies is not restricted to methods developed with transportation in mind, but to whatever is relevant to a specific problem – as we said, transport studies has a leaning towards pragmatism. In fact, many methods that were initially developed for other problems have widespread use in transportation studies. These include methods used to collect primary data, such as questionnaires and interviews. Some analytical techniques are straightforward to implement and interpret, such as graphs, tables and maps. Others are more complex, such as inferential statistics like the t-test, analysis of variance, regression and chi-square, and logit and probit models. Increasingly, transportation studies are concerned with impacts and public policy issues. They rely more on qualitative information such as policy statements, rules and regulations. Various types of impacts are considered, including economic (e.g. community development), social (e.g. access to services), environmental (e.g. air or water pollution) and health (e.g. road accidents). The broad fields of environmental impact assessment, risk assessment and policy analysis are relevant to these issues.

CONTEMPORARY TRANSPORTATION SYSTEMS

Driving forces

The era following World War II has seen a considerable growth in transport demand related to individual (passengers) as well as freight mobility. This growth is jointly the result of larger quantities of passengers and freight being moved, but also the longer distances over which they are carried. Recent trends underline an ongoing process of mobility growth, which has led to the multiplication of the number of journeys involving a wide variety of modes that service transport demands.

Despite the high capital and operational costs of modes such as ships and planes, costs per unit transported have dropped significantly over the last decades. This has made it possible to overcome larger distances and further exploit the comparative advantages of the global economy. As a result, despite the lower costs, the share of transport activities in the economy has remained relatively constant in time.

These trends have obviously extended the requirements for transport infrastructure both quantitatively (capacity) and qualitatively (performance/reliability). This has made transportation more dependent on finance as it represents a substantial sector of capital accumulation. Roads, harbors, airports, telecommunication facilities and pipelines have expanded considerably to service new areas and add capacity to existing networks. Transportation infrastructures are thus a major component of land use, notably in developed countries.

A global perspective

The structure of the global land transport network is a function of the density and intensity of economic activities as well as efforts made to access inland resources (Figure 1.1). It is important to underline that while at the global level road and rail networks appear to be integrated and interconnected, this is far from being the case. Road networks are designed to service local and regional flows and fewer corridors are used for long-distance trade. Most rail networks are national with limited international services with the exception of Europe and North America. Still, different loading gauges remain impediments to the realization of a true pan-European rail network. The North American rail network is integrated but different segments are owned by different carriers.

Container ports are reflective of the world's commercial geography particularly since they dominantly handle finished goods and parts. The world's most important ports were North American (e.g. New York) and Western European (e.g. Rotterdam). Containerization completely changed the world's commercial geography with the emergence of new major port locations reflecting changes in the global geography of production and consumption (Figure 1.2). This geography indicates a high level of traffic concentration around large port facilities, notably Pacific Asian ports along the Tokyo to Singapore corridor. As export-oriented economic development strategies took shape, the number of containers handled in Pacific Asian, notably Chinese, ports surged.

There is also an evolving geography of container ports where there is a specialization between container ports acting as gateways and container ports acting as intermediate hubs. Gateway ports command access to large manufacturing or market regions, and Hong Kong, Los Angeles and Rotterdam are notable examples. Intermediate hub ports (or offshore hubs) act as intermediary locations where containers are transshipped between different segments of the global maritime

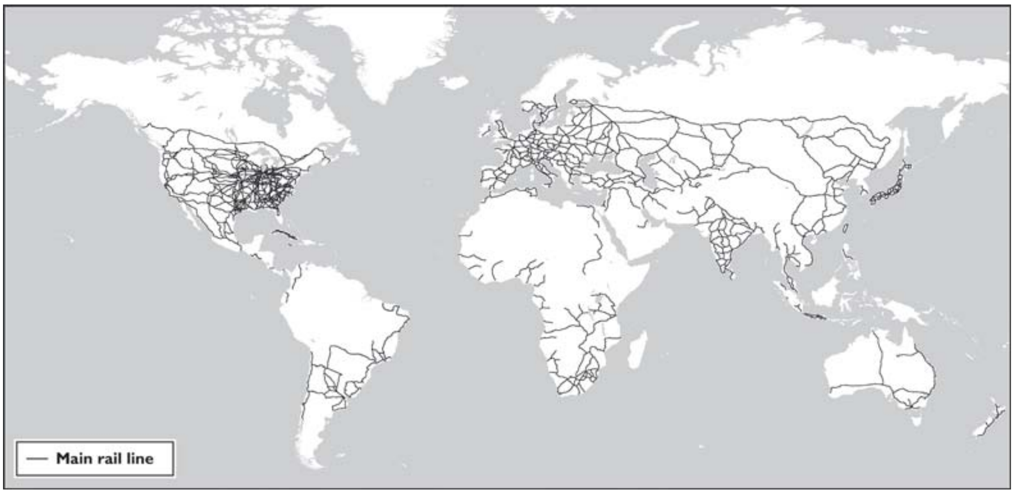

Figure 1.1 The world's main rail networks

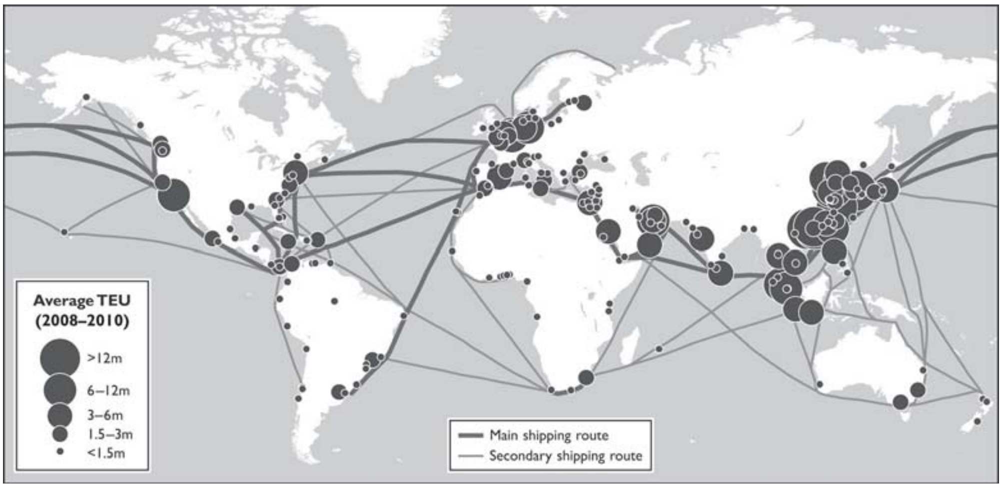

Figure 1.2 The world's major container ports, 2008–10

transport system in a manner similar to hubs in air transportation. Singapore and Dubai are among the most prominent transshipment hubs, each servicing a specific transshipment market.

The most important airports enjoy either centrality within one of the world's foremost city-regions, intermediacy between key markets, or both. There are three major concentrations of airports where the world's air traffic is articulated: Eastern North America, Western Europe and Japan (Figure 1.3). The key airports of these concentrations, or rather the main airport cities since they have more than one airport, are New York, London and Tokyo. They correspond to the world's most prominent cities and the most important financial centers, and have developed to host a series of related activities such as distribution centers, just-in-time manufacturers,

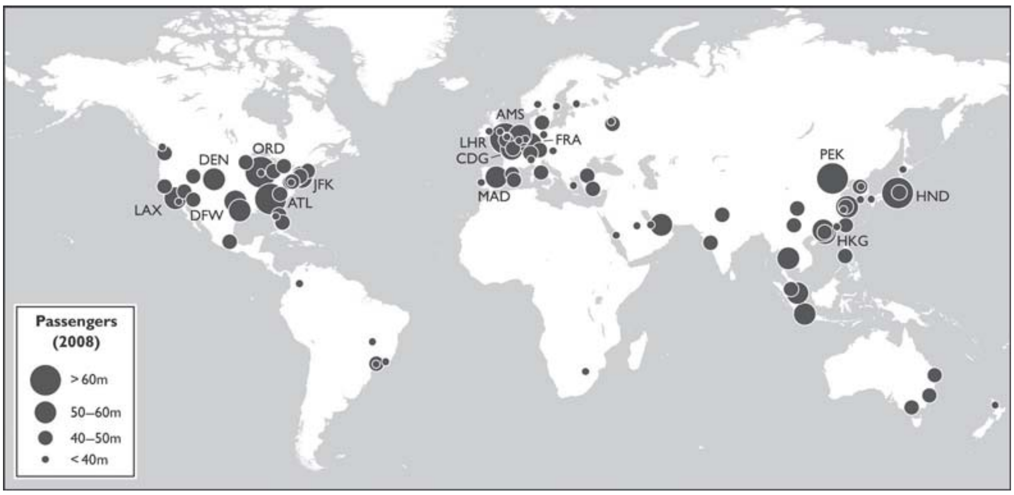

Figure 1.3 Passenger traffic at the world's largest airports, 2008

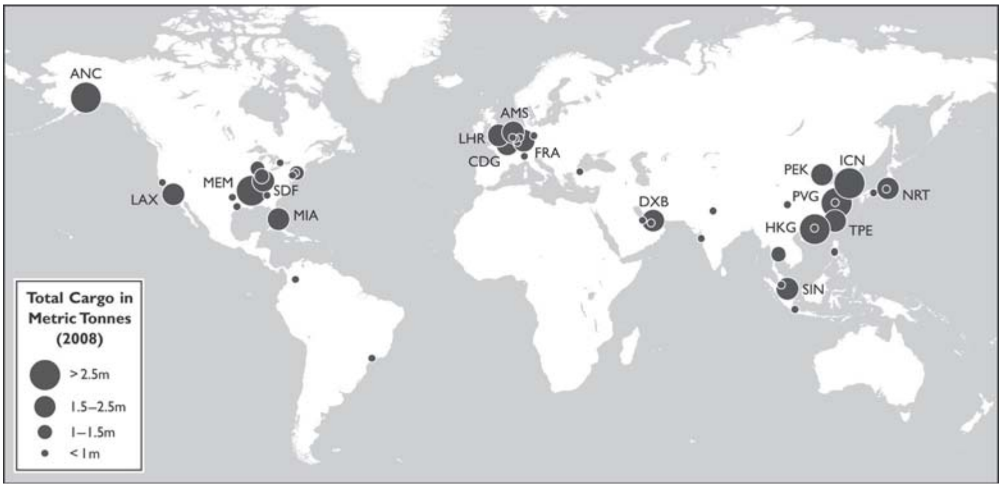

Figure 1.4 Freight traffic at the world's largest airports, 2008

office parks, hotels, restaurants, and convention centers. While there is a direct relationship between the level of air passenger traffic and the primacy of a city in the world urban system, as in the case of the geography of container ports change results from both the emergence of new cities of global prominence and the rapid development of intermediate hubs such as Dubai.

The level of freight activity at airports tends to be different than from that of passenger, especially in the United States (Figure 1.4). The Midwest being the demographic and economic centroid of the United States, many airfreight forwarders have located their hubs at airports such as Memphis (Federal Express) and Louisville (UPS) that generate little passenger traffic. The importance of Pacific Asian airports is linked with the specific role of the region in the global economy, especially in relation to electronics. Since these products tend to have a high value-to-weight ratio, air transport is particularly suitable for their shipping to North American and Western European markets. Because long-distance cargo planes have had less range than passenger planes, two airports have traditionally played a notable intermediate role: Anchorage (Pacific Asia – North America traffic) and Dubai (Pacific Asia – Western Europe traffic).

The development of fiber optic transmission technology provided a substantial impetus in the setting of a global telecommunications network since it permitted significantly higher bandwidth and less signal degradation. Throughputs of hundreds of gigabytes of information per second became possible. The first transatlantic fiber optic cable (TAT-8) was laid in 1988 and over the years fiber optic cables were laid across the world, connecting economies and societies increasingly dependent on telecommunications (Figure 1.5). The internet could not have existed otherwise. While initial submarine cables were laid on a point-to-point basis, technical advances permitted branching so that one cable could service a sequence of hubs (e.g. Africa and Latin America). The global network is designed for redundancy as several cables are laid in parallel for major connections (transatlantic and transpacific), implying that a failure in one cable can be mitigated by rerouting traffic to the others. In recent years, Pacific Asia has seen significant submarine cable laying activities, in support of its economic development.

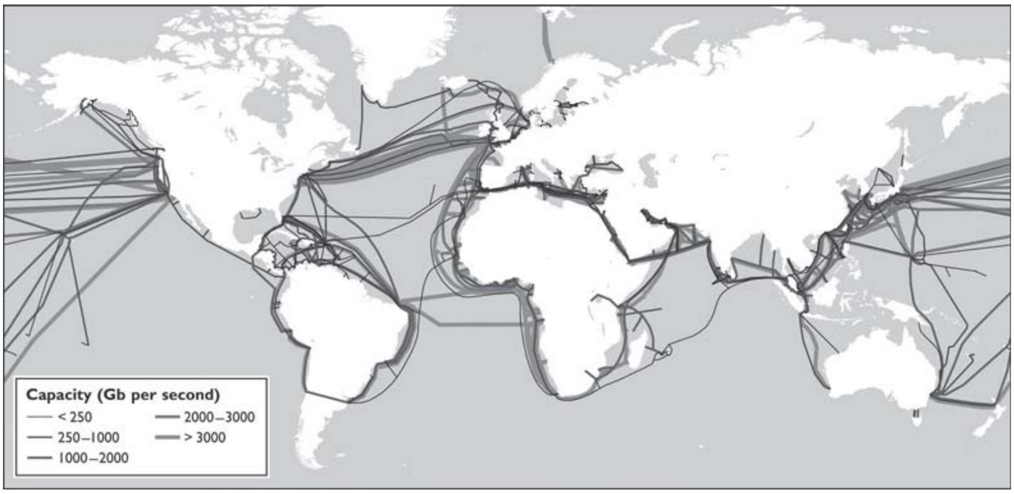

Figure 1.5 Global submarine cable network

Source: dataset encoded by Greg Mahlknecht, http://www.cablemap.info

A LOOK AT THE FUTURE

Transportation studies, by offering a broad perspective over the existing pattern and process of transportation systems, also offers ways to glimpse at future developments. Casting back over transport developments since the industrial revolution underlines that each mode, due to its geographical and technical specificities, has been characterized by different technologies and different rates of innovation and diffusion. A transport innovation can thus be an additive force where a new technology expands or makes an existing mode more efficient and competitive. It can also be a destructive force when a new technology marks the obsolescence and the demise of an existing mode. Still, in many cases an older technology will endure because of its wide level of adoption, utilization and accumulated capital investment. This is commonly known as path dependency. Vested interests in an existing mode – a good current example being the car – may also delay or impede an innovation (see Geels et al., 2012).

Historically, technological innovation is linked with faster and more efficient transport systems. This process implied a space–time convergence where a greater amount of space could be exchanged with a lesser amount of time. But one of the pitfalls in discussing future trends resides in looking at the future simply as an extrapolation of the past. It is often assumed that the future will involve a technology that already exists, but simply operating an extended scale beyond what is currently possible. This can be seen as an incremental change bias. The parameters of such an extrapolation commonly involve a greater speed, mass availability, a higher capacity and/or a better accessibility, all of which imply similar or lower costs.

The prediction of future outcomes generally considers what is within the realm of forecasting and scenario building. Forecasting tries to evaluate near-term outcomes by considering that parameters do not change much, while scenario building tries to assess a series of possible outcomes based upon expected fluctuation in parameters. A common failure of such predictions is their lack of capacity to anticipate paradigm shifts brought about by new technologies as well as economic and social conditions. But then care should also be taken not to assume the massive diffusion of any game-changing new technology over a very short period of time (the so-called "silver bullet effect"). This rarely takes place as most innovations go through a cycle of introduction, adoption, growth, peak and then obsolescence, which can take several years, if not decades. Even in the telecommunications sector, which accounts for the fastest diffusion levels, the adoption of a technology tends to take place over a period of about ten years.

Some speculations

Since the introduction of commercial jet planes, high-speed train networks and the container in the late 1960s, no significant technological change has impacted passengers and freight transport systems, at least from a paradigm shift perspective. The early 21st century is an era of car and truck dependency, which tends to constrain the development of alternative modes of transportation, as most of the technical improvements aim at insuring the dominance of oil as a source of energy. With concerns about oil reserves, however, there is strong evidence that the end of the dominance of the internal combustion engine is approaching. Energy prices are expected to remain high (and indeed continue to rise) in relation to their 1990–2000 price range, and trigger the most important technological transition in transportation since the automobile. In such an environment several transport technologies look promising.

Automated/intelligent transport systems refer to the development of a set of information and communication technologies (ICTs) to improve the speed, efficiency, safety and reliability of movements. These systems could involve the improvement of existing modes, such as automated highway systems or the better provision of information to drivers, or the creation of new types of nodes and transshipment systems in public transit and freight transportation (e.g. automated terminals). The goal of such initiatives is mainly to use existing infrastructures more efficiently through information technologies, and many gains still remain to be achieved through the better management of existing infrastructures and vehicles.

There is also a range of alternative technologies, modes and fuels that could replace but more likely complement existing modes, particularly for the transportation of passengers. One technology is maglev, short for magnetic levitation, which has the advantage of having no friction (except air friction), enabling operational speeds of 500–600 km per hour to be reached (higher speeds are possible if the train circulates in a low pressure tube). On the other side of the mobility spectrum urban transportation shows some potential for a more effective use of alternative modes, particularly in car-dependent cities and this for passengers and freight transportation alike. For instance, various public transit schemes such as light rail systems, on-demand transit vehicles, not forgetting the bicycle, may help support urban mobility.

Alternative fuels mainly concern existing modes but the sources of fuel and/or the engine technology are modified. For instance, hybrid vehicles involve the use of two types of motor technologies, commonly an internal combustion engine and an electric motor. In simple terms, braking is used to recharge a battery, which then can be used to power the electric motor. Although gasoline appears to be the most prevalent fuel choice for hybrid engines, diesel has a high potential since it can also be made from coal or organic fuels. Diesel can thus be a fuel part of a lower petroleum dependency energy strategy. Hybrid engines have often been perceived as a transitional technology to cope with higher energy prices. There is also a possibility in this regard of greater reliance on biofuels as an additive (and possibly a supplement) to petroleum, but their impacts on food production must be carefully assessed.

More far-reaching in terms of energy transition are fuel cells, which involve an electric generator using the catalytic conversion of hydrogen and oxygen. The electricity generated can be used for many purposes, such as supplying an electric motor. Current technological prospects do not foresee high output fuel cells, indicating they are applicable only to light vehicles, notably cars, or to small power systems. Nevertheless, fuel cells represent a low environmental impact alternative to generate energy if the hydrogen can be generated in a sustainable manner. Additional challenges in the use of fuel cells involve hydrogen storage (especially in a vehicle) as well as establishing a distribution system to supply the consumers.

Still, anticipating future transport trends is difficult. Technological change has historically created paradigm shifts and is likely to do so again in the future, but not necessarily in ways or with consequences that we might currently expect. There is an expectation for change, because existing transport systems are highly beneficial but at the same time beset with externalities such as congestion, pollution and CO_2 emissions. But congestion and pollution have proved resilient problems – one of the major concerns in London in the late 19th century was that by the mid-20th century the amount of horse manure generated by transport activities would become unmanageable – and the emergence of transport's role in promoting climate change reminds us how, alongside benefits, technologically-driven shifts in a transport system can result in consequences every bit as (or more) harmful as those they originally resolved.

HANDBOOK OVERVIEW

In what follows we have assembled a range of contributions on a range of topics from renowned international experts. Together the chapters speak to the main issues in contemporary transportation studies by developing our brief introductory discussion. We would be the first to say that the coverage of the book is not exhaustive in the sense of seeking to address the detail of every flow or movement pattern, or of every operational or policy area. Such an approach would require an encyclopedia. But in reading this handbook you should gain a solid understanding of the principal features, characteristics and consequences of transport systems as they have developed around the world, in relation to the movement of both freight and passengers. Further reading can be found in the references section to each chapter, and as already mentioned the *Handbook of Mobilities* (Adey et al., 2013) provides a thoroughgoing exposition of this related paradigm.

We have divided the chapters into six sections. The first two of these, *Transport in the global world* and *Transport in regions and localities* recognize the nature, extent and functionality of transport systems across and between different scales. The remaining sections – *Transport, economy and society*; *Transport policy*; *Transport networks and models*; and *Transport and the environment* – reflect numerous ways in which transport systems and activities are fundamentally connected with broader imperatives and, as such, how and why they are planned and managed.

At the broadest scale, the configuration and operational characteristics of *Transport in the global world* are related to the division of production by multinational corporations. The main expression of this is a global network of gateways and hubs that command access to vast production and consumption markets (Chapter 2). As such, transportation and transport policy are truly international issues requiring concerted efforts of transborder cooperation and coordination (Chapter 3), even more so in recent years as heightened safety and security concerns have forced the adaptation of transport actors. Major changes in international transportation have taken place in recent decades, key among which has been the adoption of containerized freight shipment, and the related integration of several modes into a continuous chain, known as intermodal transportation, has led to very significant productivity improvements (Chapter 4). While for long-distance passenger movements, air transportation has grown to be the main service provider (Chapter 5), this domination can be challenged in some regional markets by high-speed rail. Maritime transportation (Chapter 6) is the dominant mode for long-distance freight movements but air freight has been very successful at establishing niche services mainly for high-value goods.

In *regions and localities*, a very specific but highly important type of mobility concerns urban areas where large numbers of passengers and significant amounts of freight are moving over short distances. This brings sharply into focus the relationship between transport and urban land use (Chapter 7) and the important field of city logistics (Chapter 8). The siting and setting of airport terminals (Chapter 9) is inevitably interlinked with the effective functioning of the transport system of any urban area and, indeed, logistics – the comprehensive management of transportation – has been responsible for many improvements in the reliability and performance of transportation systems. The emergence of supply chain management underlines a growing integration of production, distribution, transportation and retailing in a streamlined system, which has been linked to specific forms of agglomeration such as logistics zones (Chapter 10). Such zones are served by a variety of inland terminals that underpin intermodal transport development (Chapter 11) and often act as load centers for their respective markets.

Transportation has obvious links with the *economy and society*. It is an economic activity on its own as well as a support for other activities; it is largely but by no means completely a derived demand. Transport markets (Chapter 12) employ labor, necessitate investments in infrastructure and confer a level of accessibility to resources and markets. There is a clear consensus that transport and economic development (Chapter 13) are interrelated, but what is less clear is the nature and extent of this relation, such as the growing divergence between transportation and economic growth. Transport is also crucial in underpinning a wide range of societal functions by enabling people to access goods and services. Of course, mobility is only one aspect of accessibility – information and communications technologies (ICTs) offer a new form of accessibility to goods and services and it is clear that the impacts of ICTs on travel behavior (Chapter 14) have been many and varied. In part this is because transport enables people to maintain face-to-face social networks and, through these, build and maintain social capital. People who are unable to access goods, services and social networks/capital can be regarded as socially excluded (Chapter 15).

Governments and various agencies have a significant role in the scope, operation and regulation of the transportation sector within and between their jurisdictions. Through a variety of *transport policy* instruments (Chapter 16) they can intervene in ownership, sometimes taking direct control through nationalization or, conversely, favoring an environment where the private sector is the main actor. Historically, transportation has been a highly regulated industry but recent decades have mainly been characterized by a push toward deregulation, with competition and the new market entry becoming more prevalent. This has had notable impacts on pricing and subsidy (Chapter 17). A further key policy concern is the influence of transport systems on the health of society (Chapter 18). In addition to direct effects such as accidents and the impacts of transport-related pollutants, the increased reliance on mechanized transport, especially the private car, is resulting in potentially harmful long-term health consequences.

Transport planning aims to evaluate the consequences of socioeconomic trends on transport systems as well as seeking to determine what potential consequences, positive or negative, may result from changes in existing transport infrastructures. We have already noted that Chapter 7 focuses on the relationship between transportation and land use, but here our focus is on *transport networks* and the *models* that can be used to simulate the behavior of transport systems. Modeling techniques related to transport flow, distribution and allocation (Chapter 19) and to the structure and dynamics of transport networks (Chapter 20) are examined, as are locational transport models (Chapter 21) and ways in which incident and emergency traffic management can be modeled and addressed (Chapter 22).

Of increasing importance in the context of policy approaches taking cognizance of concerns about climate change, is the relationship between *transport and the environment.* Transportation systems are commonly significant contributors to a variety of environmental externalities, and the transportation sector is a large consumer of energy – particularly petroleum – so the dynamics of transport and energy use (Chapter 23) are intrinsically linked. From global climate change to local noise, the environmental impacts of transportation are complex and difficult to mitigate (Chapter 24). Finally, since production, transportation and distribution are embedded, it is in the supply chain that many environmental benefits can be realized either directly, such as reverse distribution, or indirectly through energy efficiency; this is the realm of green logistics (Chapter 25). Even if sustainable transportation is ultimately an evasive goal, it has become a conceptual and ideological framework to which transport planning, policy and management are increasingly responsive.

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