# FREIGHT TRANSPORT MODELING IN EMERGING COUNTRIES




EDITED BY
IOANNA KOUROUNIOTI • LÓRÁNT TAVASSZY • HANNO FRIEDRICH



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# Preface

This book is an initiative of the Special Interest Group on Freight Transport Modeling (SIG-B5) of the World Transport Research Conference (WCTR). It was created by a team of experts with interest and experience in different aspects of freight transport modeling in emerging countries. The idea for the book emerged from an encouraging observation during the 2016 WCTR in Shanghai that many developing and emerging countries used creative, non-standard solutions to create freight models, which were not widely known. Some of these revolved around smart use of traditional simplified transport models, others used sophisticated approaches for data fusion or employed original data sources. As such these cases could inspire also new modeling initiatives in developed countries, although, it was also clear that many times the context of these countries was so specific that the transfer of known models was not possible. Emerging countries experience rapid changes in economic development, structural changes in both domestic and international freight flows, new policy priorities, new governmental and regulatory structures, volatile rates of growth and technological diffusion, transitions from traditional to modern logistics systems, new market conditions for logistics industries, etc. A transfer and application of models, already developed in other countries, is not always effective as they lack a representation of these problems.

This book provides many different examples of successful freight transport model applications, alternative data collection methods, and evaluation techniques for the development of future policies. Policy makers and transport modelers can get insights from national and regional model practices in Turkey, India, South Africa, Indonesia, and Chile. Students of transport systems in engineering and management schools, as well as researchers in transport modeling will find several interesting methodological and data collection approaches.

The newly launched joint WCTR-Elsevier book series on transport research provided the opportunity to create this volume. The group of authors first came together in a workshop on the island of Chios, Greece in June 2018, to discuss the draft papers on the topic. We discussed the peculiarities of freight transport modeling in emerging countries, identified gaps in the literature and agreed on a common framework for analysis.

We are indebted to the World Conference Transport Research Society (WCTRS) book series Editorial Board (Chair: Prof. Füsün Ülengin) and the responsible Elsevier editor Brian Romer for their comments on the first plans for the book and the kind guidance provided during its writing. We are grateful for the Department of Shipping Trade and Transport, University of the Aegean and the Maria Tsakos Foundation for hosting the workshop in Greece. Finally, we would like to thank all the contributors of this book for their efforts and valuable inputs to the book.

**We hope that you find this book insightful and educational.**

**The editors**

# Introduction

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Freight transport is increasing globally as a consequence of economic development. In emerging economies, where economic development is most dynamic, this is especially true. Politicians and logistics managers in these countries need to make sure that appropriate infrastructure and logistics services are available to support this growth. Their decisions should be supported by proper analysis of freight transportation systems and the development of analytical models. But this is challenging for multiple reasons, for example, the limited data availability or the speed of change. In this book, we want to explore experiences that already exist in different emerging countries.

Each chapter will discuss insights from a country, region, or corridor. To better understand the contributions, we use the categories defined in a study by De Jong et al. (2016) who clustered the issues in freight transport modeling into four categories:

- Requirements: defining the right question, scope, and level of detail
- Institutional: organizing model development and confidence in model outputs
- Specifications: choosing or developing the right approach and methodology
- Data: using existing data sources, collecting new data, or handling limited data availability

In Fig. 1, we tried to allocate the chapters to one or more of these four categories.

The book contains 12 chapters with contributions from different countries all over the world. The book is structured into two parts. The first part (Chapters 1–5, light gray in Fig. 1) contains contributions that rather describe the approach, and the second part (Chapters 6–11, dark gray in Fig. 1) contains contributions that rather focus on the application.

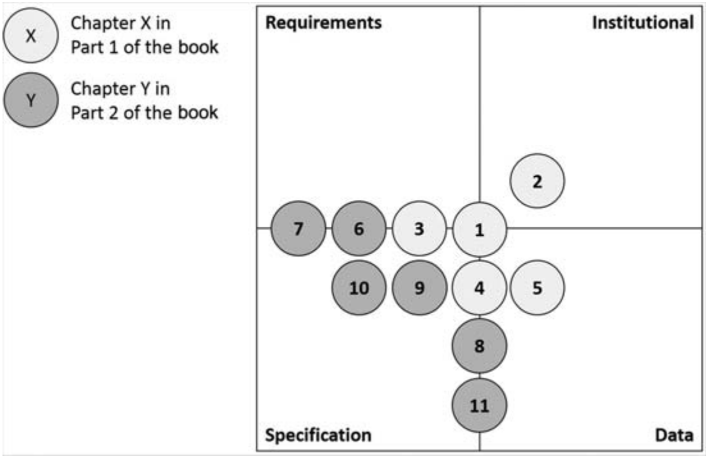


**FIGURE 1** Allocation of chapters to different categories.

The first part of the book starts with Chapter 1 in which Dilay Celabi explains the specifics that make freight transport modeling challenging in emerging countries, including all four dimensions. Fundamental changes in regulation and market structures are examples of this. She bases her reflections on insights gained from the experiences with the national freight transport modeling practices in Turkey.

Geographically close (to Greece), Anagnostopoulou and Boile focus on the institutional dimension in Chapter 2. They present a framework for stakeholder consultation in freight transport planning in port cities and discuss the different perspectives of the private and public sectors. Taking the example of Thessaloniki, they analyze the reduction of energy consumption as an example where both share the same objective.

Rather taking the public perspective, Tapia and Sicra discuss the requirements of interregional infrastructure corridors for models in Chapter 3. They base their considerations on examples from South America. They demonstrate how important a good understanding of the freight transport system is to define good policies and to formulate the requirements for appropriate models.

The next two chapters discuss available data sources and corresponding modeling approaches: in Chapter 4, Simpson et al. propose an approach of a spatially and sectorally detailed freight flow model that provides information availability and infrastructure requirements of emerging countries. They especially address the issue of limited funding, using available data from government and industry sources instead of requiring primary data research.

A disaggregate data source that is potentially available for freight transport modeling is discussed by Tapia in Chapter 5: tax revenue data. He explains how the data can be processed to make it usable and demonstrates how this was used in Brazil and Argentina to generate origin–destination matrices and data for disaggregate choice models. This terminates the first part of the book.

The second part of the book rather focuses on the application of models and starts in Chapter 6 with an analysis of maritime transport networks in Indonesia. Verhaeghe et al. describe network optimization approaches for the network of combined passenger/cargo ferries and for the (pure) interisland container transport networks.

Looking at another maritime country, Tsirimpa and Kapros analyze the impact of the economic crisis in Greece on logistics and freight transport in Chapter 7. They present a mode choice model and analyze the impact of the crisis on the values of time for freight transport.

Also addressing different modes, Simpson et al. apply their freight demand modeling approach in South Africa and India in Chapter 8. In the case of South Africa, this includes the analysis of intermodal solutions in India, the integrated planning between road, rail, ports, and inland waterways on dedicated freight corridors.

One of the most interesting rail corridors in recent years is the focus of Meersman et al. in Chapter 9. They analyze to what extend rail will become a real competitor in the corridor between China and Europe. Using insights from existing studies, they develop different scenarios and apply a generalized cost approach for the different transport alternatives, to explain the potential selection.

A much more local analysis is the freight demand model for the city of New Dehli in Chapter 10. Errampalli and Tavasszy use the traditional four-stage modeling approach and analyze different policy scenarios, including replacing diesel vehicles or establishing new freight hubs.

On a more operational level, Kourounioti develops a model to predict the distribution of workload during the day in a container terminal of a Middle East port in Chapter 11. Using available aggregate data, the model can be used to increase the planning efficiency in the terminal.

Finally, in Chapter 12, we synthesize the contributions of the chapters in the four categories introduced in the beginning: institutional, specification, requirements, and data.

## Reference

de Jong, G., Tavasszy, L., Bates, J., Grønland, S.E., Huber, S., Kleven, O., et al., 2016. The issues in modelling freight transport at the national level. Case Stud. Transp. Policy 4 (1), 13–21.

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Chapter 1

# Issues in freight transport modeling for emerging economies: insights from Turkey

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## Highlights

- Identification and discussion of the freight modeling issues in emerging countries.
- Description of Turkish approaches to solve these issues.

## 1. Introduction

Although there is an interesting and growing number of studies addressing freight transport modeling for several developed countries (e.g., Tavasszy et al. (1998a), Beuthe et al. (2001), Limbourg and Jourquin (2009), Liedtke (2009), Friedrich (2010), Samimi et al. (2010), Ben-Akiva et al. (2013)), little research has been published for emerging economies. Generally, the existing models provide a good starting point for analyzing certain issues in freight transportation systems. However, they may lack the representation of characteristics that are specific to emerging economies. This chapter seeks to identify the issues specific to freight transport modeling in emerging economies by carrying out a review of the literature and some insights gained from the experiences from national freight transport modeling practices, with a focus on Turkey. Specifically, it gives a discussion of freight transport modeling concerns that are present in the context of emerging economies, based on the main issues in modeling freight transport at the national level compiled by de Jong et al. (2016). These issues are not restricted to emerging economies, and they

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do not exclude those issues that also occur in developed countries. This study can be a starting point for building emerging economy; specific models are tailored for solving the modeling requirements characterized by the freight transportation systems.

## 2. The issues in modeling freight transport at the national level

There is not a one-size-fits-all formula for national freight models. Depending on the country-specific characteristics, existing models differ in terms of their purpose, the data used, and their depth of aggregation, in corresponding measurement variables used, and in their scale of analysis. However, there are general requirements and challenges shared by all existing models (Wigan and Southworth, 2005).

A review of the main issues to consider in the modeling of freight transport at the national level is classified under four main headings by de Jong et al. (2016), as illustrated in Fig. 1.1.

In more detail, institutional aspects refers to the organization of the work on model development and use, as well as how confidence in these models can be determined and increased. Modeling requirements covers the questions about the purpose of the model and its scope and level of detail. Model philosophy and influencing factors are included in specification aspects, with discussions of new directions, such as the trend to include more aspects of logistics decisions of firms. Finally, issues related to determination of data requirements, data collection, and availability are

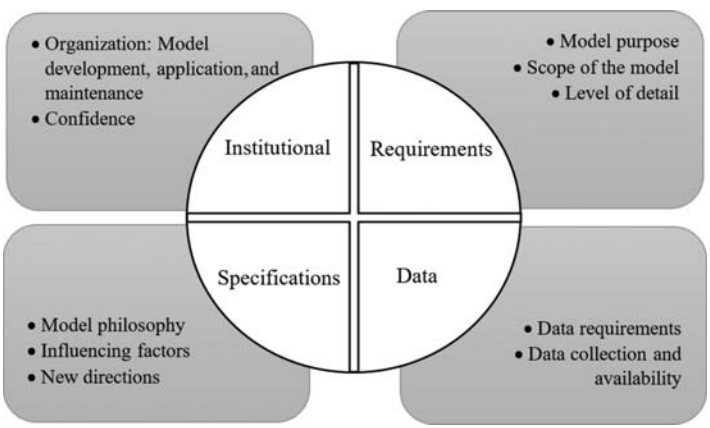


**FIGURE 1.1** Issues in modeling freight transport at the national level. *Adapted from deJong, G., Tavasszy, L., Bates, J., Grønland, S.E., Huber, S., Kleven, O., et al., 2016. The issues in modelling freight transport at the national level, Case Stud. Transp. Policy 4 (1), 13–21.*

grouped under the title data. We will use this structure to discuss freight transport modeling concerns that are specific to the context of emerging economies in the following sections.

## 3. Concerns in freight modeling for emerging economies

### 3.1 Institutional aspects

Typically, various components and elements of current transport systems are operated and regulated by different governmental agencies and private operators. In many cases, there is little coordination among those responsible for the operation of the various elements of both national and urban transportation systems. This results in each agency and operator attempting to improve those elements under its jurisdiction without consideration of the efficiency and effectiveness of the overall transportation system and sometimes at the expense of the other elements of the various modes of transport. Although this is a common characteristic for both emerging economies and developed counterparts, coordination mechanisms among related agencies are less mature in emerging economies, as they are likely to emerge with the growing economic complicacies in fairly large, open, and mature economies (Van Brabant, 2012).

The lack of coordination among agencies creates confusion in determining the objectives of the freight model. In Turkey, various studies are conducted simultaneously both in national and regional levels without any guidance from a national plan, producing a number of logistics and transportation plans, which generally fail to take into account the findings of each other. There are more than 10 regional logistics master plans prepared by local governments, focusing on a particular geographical region. These plans lack coherence, both in terms of methodologies and objectives. The scope of models used in these plans is generally set to the particular geographic area, bounded by the regional borders, ignoring the interactions with neighboring regions or relations to higher level plans. For example, there are three separate feasibility plans for constructing logistic centers in three locations (Karaman, Gaziantep, and Şanlıurfa), which are not far from each other more than 120 km. Models used in these plans are independent of each other and do not consider the changes in freight flows that may arise because of the development plans in the neighboring regions.

The principal problem in weak coordination in governance for freight modeling is the difficulty in planning the organization of modeling efforts, where continuity is of prime importance (de Jong et al., (2016)). A stable organizational environment that commits to the development, maintenance, and use of national freight transport models is important for success. However, in Turkey, different bodies and agencies in the government level share the responsibility of freight transport planning, each dealing with a different aspect. Control and planning of various freight transportation−related aspects are diversified among the Ministry of Transportation (MOT), the Ministry of Development, the Ministry of Economics, and the Ministry of Customs and Trade. However, effective coordination among the responsible authorities, which is necessary for the design of a coherent system, is lacking. As a result of the lack of a governance structure for orchestrating and controlling the planning practices in those different authorities, disagreements and sometimes conflicts naturally exist in the planning objectives and scope of the models covered in the plans prepared for those agencies. The dispersion of authorities is not necessarily broad, even under the same governance body; conflicts can be observed among diversified plans prepared by different directorates because of ill-structured control and planning mechanisms. For example, three different freight-related plans—Logistics Masterplan, Transportation Masterplan, and Maritime Development Masterplan—are prepared by the MOT in Turkey, which are all controlled by different directorates. They show a great amount of disparity in terms of methods implemented in predicting freight flows, in the data they use, and accordingly, in the results they obtained. Furthermore, the lack of coordination and distributed authority creates a competitive environment among different bodies, which even result in unwillingness in data sharing and creation of obstacles for other plans and policies.

As a response to the abovementioned issues in the development of logistics models, Turkish MOT has currently issued a declaration, suggesting that all logistics-related development plans should be developed in alignment with the national logistics masterplan, which is, in turn, developed in alignment with the national development objectives set by the Directorate of Strategy and Budget and Ministries of Industry and Technology, Trade, and Transport and Infrastructure.

Another emerging economy−specific issue in organization of freight modeling arises with lack of accountability and responsiveness because of the conflicts in regulatory structure and ill-controlled governance. The average burden of regulations is the least among the high-income countries on a comparative basis and increases progressively as per-capita income declines (Hafeez, 2003). Compared with Organisation for Economic Co-operation and Development countries, companies operating in emerging economies generally deal with more regulatory constraints, including price controls, regulations on foreign trade and currency, tax regulations and/or high taxes, policy instability, and general uncertainty regarding the costs of regulation (Tybout, 2000). High level of ill-structured regulations creates significant difficulties and complications in modeling freight systems and in making reliable predictions for the evolution of industrial and transport systems. As a result, developing freight models for systems controlled by high level of regulations requires modelers to navigate a myriad of complexities, uncertainty, and rapid structural changes that determine the behavior of the logistics industry. For developing a realistic and correctly defined model, the regulatory intricacy should be resolved, and the decisions relevant to freight flows should be modeled under the consideration of the regulatory interferences. Moreover, models should be developed to allow designing scenarios for simulations for various policy interventions and analyzing the impacts of policy measures on freight flows and the environment (e.g., SMILE by Tavasszy et al. (1998b)). System dynamics approach may be helpful to analyze interdependencies between policy interventions and freight transport demand along the entire transport chains. A well-working example for Europe is ASTRA (Assessment of Transport Strategies), which is used for the strategic assessment of policy scenarios, taking into account feedback loops between the transport system and the economic system (Fiorello et al., 2010). System dynamics models, however, usually do not contain sufficient spatial and network details to yield zone-to-zone flows and link loadings.

## 3.2 Requirements

The scope of the model and the level of detail of a freight model depend strongly on the issues under investigation. Typical questions include freight flow forecasts, factors influencing vehicle type and route choice, spatial and economic effects, optimal location of logistics centers, and effects on reliability, congestion, and environment (de Jong et al., 2016). The composition of the questions asked determines the model characteristics and required modules to be implemented. As a matter of course, freight models show disparities between developed and developing countries in terms of questions asked and modeling requirements. A major difference lies in the purpose of the model because of structural differences and policy priorities.

Many emerging economies suffer from structural problems, which affect the industry, economy, and transport systems. One of these is the urban–rural divide, which describes differences between urban and rural areas in access to transportation. The urban–rural divide is more common in the developing world than in the industrialized world, usually with rural areas being worse off than urban areas (Ellis, 2000). Because the impact of investments in urban areas is higher and more direct, policymakers tend to favor urban areas in setting investment priorities. On the other hand, it has to be noted that national and international policymakers regularly stress the importance of increasing basic human needs, infrastructure, and economy in rural areas. Many emerging economies, such as China (Parish, 2016), Nigeria (Filani, 1993), India (Maparu and Mazumder, 2017), and Nepal (Byg and Herslund, 2016), therefore, have rural development schemes in place for years. Fig. 1.2 illustrates industrial location quotients of different regions of Turkey (in NUTS2 (Nomenclature of Territorial Units for Statistics, Second Level) classification) for years 2007 and 2017. This figure shows not only the disparities among the regions but also the high rates of change in industrial development for each region only within 10 years. For example, industrial intensity of southeastern regions (TRC3) decreases rapidly, mainly because of the political instability in the area. Meanwhile, as a response to increase in share of service sector, a decline in industrial intensity is also visible for İstanbul region (TR10).

These structural differences among the regions generate difficulties in both freight generation (generation of regional O-D matrices) and distribution (the assignment of O-D matrices for freight demand), the stages of modeling. Regardless of the technique implemented by the modeler, econometric, or time series analysis, a long list of econometric, social, and geographic parameters should be investigated as determinant of the freight demand estimation and allocation models. Some of the parameters, such as economic development potential, are particularly important to reflect the transitions in emerging economics, although their estimation is equally challenging. There are numerous factors that can potentially influence economic development potential at the regional level, thereby making the task of assessing underlying variations

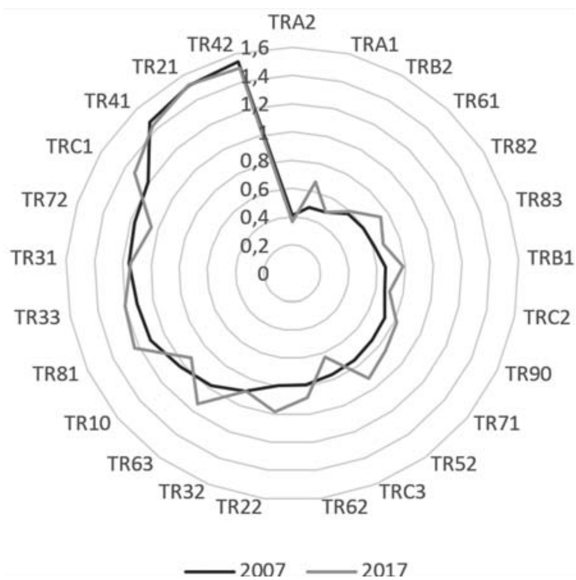


**FIGURE 1.2** Spatial distribution of industrial operations by regions. *Data source: TUIK.*

in economic potential across regions a tedious task. In the construction of a parameter to reflect economic development, modelers may need to warrant the inclusion of market access, economic density, rate of urbanization, availability of human capital, and local transport connectivity, which are found relevant by empirical evidence (Roberts, 2016). However, given the limited availability of national statistics, most of the time it is not possible to obtain the sufficient data for the wide set of possibly relevant parameters. Hence, an alternative approach is implemented in Turkish case; economic growth potential of a region is defined by its proximity in both geographical and economic terms. As a result, the reliability of the estimation models decreased, limiting the applicability of the model.

In many emerging economies, transportation sector is subject to economic deregulation in the form of reducing or dismantling barriers to entry or exit, streamlining licensing and tariff laws, and price and wage controls (Hafeez, 2003). Traditional models generally assume privatized and competitive markets, while traditionally, most emerging economies are characterized by centralized and government-controlled markets. On the other hand, many of them are still in the process of deregulation and reform of economic regulation systems. This creates a rapid growth of private sectors, a dramatic increase in foreign capital flows, and rapid evolution of markets and instruments in most emerging economies. As a result, freight transport models for emerging economies require more flexibility in terms of scope and level of detail or at least they should be designed to be extended when necessary to capture the dynamic environment witnessed in those countries. Although traditional gravity or input–output models can help in determining production and attraction or distribution steps in freight modeling, they are inadequate for analyzing implications of changes in dynamic environments. To take into account underlying changes in the economic structure, Havenga and Simpson (2018) provide a good example of a comprehensive approach to generate forecasted freight flows, achieved by creating forecasts of local demand, exports, imports, and production per commodity group for each year. Their nonsurvey-based method adapts a demand-side approach where the interrelations between sectors of an economy are analyzed and translated into flows of goods over I-O tables.

## 3.3 Specifications

National freight transport models are used for investigating what might happen to transport and transport-related indicators, such as trade and emissions in the medium to long run, and to simulate the impact of transport policy measures (e.g., pricing for a certain mode) and infrastructure investment projects, assuming fixed or adaptive model coefficients (de Jong et al., 2016). The models are expected to reflect both short-term and long-term developments in the freight systems to simulate the impact of trends and transport policy measures. Accordingly, they commonly require reflecting the impacts of major unexpected events, both in terms of economic and technological developments, depending on the issues under investigation. Typically, freight forecasting models are then constructed for different growth scenarios, which reflect potential ways forward for industrialization and trade.

Freight transportation decisions depend on a variety of market conditions. The assumption made in several models is that the market conditions will be maintained or the changes in market structure are foreseeable. This assumption is mostly valid for developed countries; yet, emerging economies witness greater levels of uncertainty in market structures. Similar to other industries, transportation industry is highly volatile in emerging economies and subjects to significant impacts caused by transformation of the overall mergers, increased competition, international agreements, and policy changes. On the other hand, emerging economies typically observe a rapid expansion of gross domestic product (GDP) and a transition of lifestyles with high urbanization rates. This involves migration to urban centers, changing consumption patterns and rising transport intensity of consumption. These dynamics have significant implications for growth in freight transport demand, trajectories of production mix, impact on environment, and infrastructure use over time. Furthermore, studies and models developed in industrially advanced countries assume well-developed markets, perfect competition, minimal trade and other socioeconomic barriers, and nonexistence of traditional economies. However, in most of the emerging economies the spatial distribution of the economic activities is still not settled, and many are in a process of rapid deindustrialization (Tregenna, 2011), which is illustrated, especially, by the constant reduction in the manufacturing share in GDP and employment and the rise in the share of service sector. This deindustrialization process can rather be attributed to the policy shifts (i.e., the radical economic reforms) than to the economic structure maturity (Palma, 2005). These changes may or may not be captured by changes in aggregated variables such as per-capita income or even through more disaggregated economic parameters (e.g., the share of transportation and warehousing in the production function of industrial sectors). To create the freight–economy linkages in these rapidly changing environments, land use–transport interaction and spatial computable general equilibrium models are commonly used, as these explain the interactions between trade, transport, and the economy (Tavasszy, 2008). Nevertheless, these models are data hungry and burdensome to calibrate; the main challenge for countries is related to preparation of national statistics such as a multiregional I/O table. In most of the emerging economies, as so in Turkey, these statistics are not available, and the relevant data are either estimated by intricate methods (which decreases the confidence levels of the models) or long and costly surveys are applied.

Understanding of such transitions is required to be reflected in freight transportation models. It would be false to say that current economic models ignore these factors. They, to some extent, capture transition factors by changes in macroeconomic parameters. However, specific aspects that need to be modeled include factors determining industrial shift from traditional to modern markets, nature and types of such shifts, and their impact on production and consumption levels, technology use, and transportation requirements. Although it is explored by models based on disaggregated input–output models that reflect long-term economic forecast (see, e.g., Chapter 5), representing such major shifts in economic structures is still a key challenge for freight transport modelers of emerging economies.

Such a structural change in transport systems is currently taking place in Turkey. Historically, the State Railways of Turkey operated rail services as a state enterprise under the MOT with monopoly powers and vertical integrated structure. A law to liberalize the rail sector was issued in 2013 for vertical separation of the rail industry, and the new code with respect to the liberalization of Turkey's rail system came into force very recently. This code removes the rail network monopoly and provides investment and operation rights to other entities, both private and public (UNECE, 2018). They are now entitled to build their own railway infrastructure, operate the infrastructure on the railways owned by themselves or others, and be train operators on the national railway network under authorization of the Ministry. Two companies have already become the first railway operators within the scope of the rail systems liberalization law, and the number is expected to increase in near future. The impact of this structural change on the Turkish transport system is likely to be high. Currently, train carries only 6% of freight in Turkey annually. Letting independent firms carry more goods and loads via train, something liberalization signals, is expected by the policymakers to increase the competitiveness of rail freight industry and bump up rail freight levels considerably. However, the extent of benefits from separation depends on the characteristics of both the freight flow characteristics and infrastructure in question. If the rail industry is characterized before separation by the existence of large, inefficient, possibly government-owned, companies as in most emerging economies, then the introduction of a combination of competition and separation can lead to substantial efficiency gains (Abbott and Cohen, 2017).

As the cost of rail transport and services offered on the rail systems change, the preferability of the route–mode combinations through the transport network would also change, requiring reconsideration of parameters used in cost minimization and freight mode choice models. Abovementioned characteristics are specific to emerging economies and are not captured in majority of the models developed for industrially advanced countries. In fact, the models usually used in freight modal split research are static, and hence, they do not consider the evolution over time of costs because of the technological and organizational changes in transport modes, which accompany the evolution of freight flow. Therefore dynamic models, such as suggested by Ferrari (2014), which assume that freight flow varies over time accompanied by corresponding variations in the characteristics of transport modes, can be more appropriate to model dynamic transport environments of emerging economies. Unfortunately, these models are difficult to implement and data intensive.

## 3.4 Data

The success of a freight model is determined by the availability, consistency, and quality of the data, which is required for examining existing conditions of the transport system, detecting changes, and forecasting future freight flows and freight transport demand. There is a significant need to access a wide array of data sources for freight modeling and analysis. The modeling of freight transport requires sufficient information on the characteristics of freight transport systems and many data on the past and present freight traffic. However, the data intensive nature of freight models hampers their applicability in emerging economies with limited data on goods movement.

Unlike many developed countries with established pathways for access to detailed transport data, emerging economies generally suffer from a lack of standards and consistent methods and instrumentation in data collection. Moreover, the use of transport data for research beyond census record keeping is very new and not considered within the purview of the relevant authorities. Therefore common practices for collecting freight transport data are not well known or widely applied in emerging economies (Neutens, 2015). As a result, the likelihood of collecting wrong or useless information is high. This was one of the obstacles encountered during preparation of the national logistics masterplan of Turkey. The roadside surveys have been subcontracted to a market research company, which has not conducted any transport-related studies before. Because of problems related to lack of experience, such as poorly worded questions, incorrect interview procedures, and inaccurate information provided by the drivers, approximately 35% of the collected data were removed because of missing values and outliers after a data-cleansing period of more than 5 months. Therefore maintaining continuity in survey instruments over time and standardizing data collection techniques are required to prevent changes in instrument bias, to support modeling techniques, and to build on the knowledge gained from previously collected data.

Moreover, the completeness of the data record is a further limitation. Lack of required details on data leaves modelers to rely on anecdotes, intuition, and lessons learned from other countries and to predict missing information by approximation techniques with respect to reference models. However, parameters and equations of regression methods or functions calculated for developed countries cannot be used as a reference to estimate parameters in emerging economy models. For example, one can expect considerable differences in parameters such as weight conversion rate or loading factor between developed and developing countries because overloading of vehicles is more common than by their underloading in much of the developing world (ADB, 2012).

Several new methods for data collection are available and are being increasingly accepted internationally as robust and reliable state-of-practice tools, such as global positioning system −assisted surveys, internet-based data collection, and a variety of Information Technology Systems (ITS)-based passive data collection techniques. Yet, in emerging economies such as Turkey, data collection is restricted to state institutions, which are generally unfamiliar with these recent trends in data collection. These state-based statistical departments also face internal and external problems. The internal problems include lack of institutional setup and weak infrastructure, whereas the external problems are the low literacy ratio and lack of awareness regarding the data collection. For example, in Turkey, the only official data on freight flow over road are the traffic counts provided by the Bureau of Road Transport. The data lack details such as product type or loading factor. Even the information about number of registered freight vehicles is contradictory. Although the rail freight data are available and complete, they correspond to less than 8% of all freight flows in the country. The share of logistics sector in economy is unknown, regional separation of production/consumption data does not exist, and sea or rail freight figures are variable by source. Analytical problems, other than poor data quality and missing data, also exist for determining how to measure some concepts and what measures of what variables should be compared with what measures of other variables. Obtaining high-quality records from regional management systems can be challenging. Especially at the urban level, hardly any transport statistics are available to help with developing freight transport demand models.

There are several threats to freight transportation data quality of particular relevance in developing country settings. These include errors due to maintaining and reporting, treatment of missing data, lack of standards about data definitions, low reliability or validity of data collection instruments, and the failure of information analysts to understand the assumptions of their analytic programming. The gathering and communication of transport information are generally fragmented in developing nations. If there are available data of the quality mentioned, collected by different agencies, it is usually for specific areas, which hampers the additivity of data and comprehensiveness of models. Lack of comprehensive data usually limits forecasts and can only provide the basis for a general overview. Regrettably, this is the situation in much of the developing world (McKinnon, 2015).

Furthermore, in emerging economies, the available data have not been greatly used by decision makers, and lack of awareness and insufficient information are the root causes. Although the importance of logistics and freight transport is highly granted, political acknowledgment of its importance often does not extend as far as the statistics bureau. On the other hand, information technologies (ITs) are getting more and more widespread, and the penetration rate is high in logistics industry. Digitalization of logistics operations and the development of IT are encouraging, as they will ease collection and management of data in emerging economies. Vehicle tracking systems are common, which may also provide information essential to fleet management such as delivery times, truck flows, estimated time of completion, the location, and speed. Emerging economies have launched a number of information initiatives in the last two decades, but the application of IT is still in its infancy and requires more effort.

Even when data needed for a standard model such as GDP, a base year OD matrix, time, and distance by mode over the transportation network are available, data needed for the estimation and prediction of future freight flows may still be scarce. To deal with uncertainties distinct from developed countries, such as the endowment conditions for infrastructure projects, the availability of a "foreign loan" to build a railway, or simply next year's capital budget for transportation projects in a region (Gakenheimer, 2006), modeler may prefer to use data to represent tacit knowledge and subjective evaluation measures to obtain better estimates. Similarly, microeconomic or network-based models are unattainable most of the time because of the data availability.

## 4. Discussion

A summary of the abovementioned issues and characteristics with some examples and their potential impact on modeling practices are shown in Fig. 1.3. In terms of institutional issues, the lack of coordination among agencies and conflicts in regulatory structures create confusion in determining the objectives of the freight model and create additional complexities and uncertainties for modelers. For developing a realistic and correctly defined model, the decisions relevant to freight flows should be modeled under the consideration of the regulatory interferences that allow conducting simulations to study the impacts of policy measures. In solving problems related to the regulatory intricacy, government intervention may be needed to ensure that freight models are developed in coherence and under the guidance of a national plan.

In terms of requirements, prominent characteristics are structural and economic differences among regions and rapid economic development and technological transitions. This structural difference between the urban and rural areas in emerging economies create additional set of constraints to be considered in the freight model. The list of relevant parameters, which are important to reflect the transitions in emerging economics, is long, and their estimation is challenging. For analyzing long-term impacts of structural changes in the production and logistics systems, novel techniques integrate economic forecasting and disaggregation methods to simulate linkages between various aggregate variables such as demand, regulations, uncertainty, investment strategies, and trade policies.

Emerging economies are far behind their stabilization levels. What makes prediction of future developments and representing the freight transport

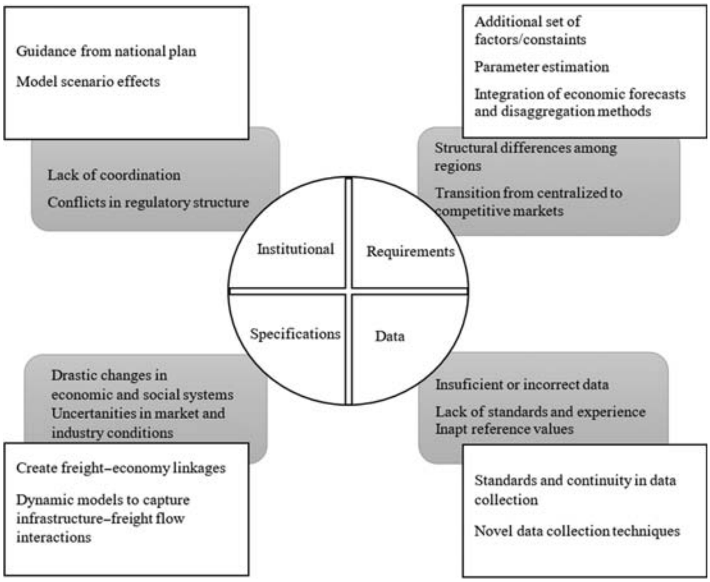


**FIGURE 1.3** Issues in freight transport modeling in emerging countries.

behavior more difficult in emerging economies countries is the complex and ever-changing environment that freight transport systems rely on. Uncertainties are observed in infrastructure development, rural development, Research & Development (R&D), privatization/regulation and trade, future demands in different end-use sectors of the economy, and transportation costs. It is essential for modelers to create the freight—economy linkages in these rapidly changing environments. On the other hand, this instability of markets provides excellent opportunities for modelers to analyze and illustrate the advantages of investment ahead of demand and demand stimulation because of investment.

Emerging economies generally experience important issues related to data availability, organization, and standardization. At this point, the choice of model(s) is determined by data requirements rather than the accuracy of the technique and the system specifications. Therefore, the first course of action for freight modeling in emerging economies can be set around finding, organizing, and standardizing the appropriate data to generate maybe less sophisticated but practical-to-use models accustomed according to the modeling objectives and model's purpose of use.

## 5. Conclusion

Conclusively, freight modeling in emerging economies is complex and faces serious challenges. Although developed country freight models are useful for addressing certain issues relating to operational improvement, impact of technology mix, and impact of certain aspects of privatization and competition, they are inadequate for analyzing a large number of policy concerns of emerging economies. Equity of distribution and sustainability of resource use, dynamics of transition from traditional to modern industries, barriers to such transition, rate of technological diffusion, ongoing changes in market structure, and long-term uncertainties in the market and governance structures are characteristics specific to most emerging economies.

Some of the present-day freight transport models formulated for developed countries can be directly adopted for analyzing similar policy and planning concerns in the context of emerging economies. However, concerns and characteristics `specific to emerging economies need to be modeled by suitably extending the basic methodological features of these approaches. Modeling frameworks, using these different approaches in complimentary manner, and specifically for the context of emerging economies, need to be developed. These discussed characteristics of the production and logistics systems of emerging economies need to be addressed in freight transport models to ensure an adequate representation and scenario making of the regional and national transport planning. Although this is a challenge for freight transport modelers, it is also an open area of research to develop approaches and models for emerging economies that adequately address the above-discussed main characteristics.

Nevertheless, using more sophisticated models to cover these issues specific to emerging economies will also increase the data requirements. Although selection of a complex model aims at increasing the overall confidence and accuracy of the results, higher confidence is not guaranteed unless accuracy of data is sufficient and model has been correctly calibrated. Given that data availability is a common issue in emerging economies, the modeler should find a trade-off between degree of model complexity and the accuracy of the results. Even if the modelers decide to make certain concessions with the quality of data used, requirements can still be high enough to make its application impossible. At this point, a major determinant of a model's practical value in planning becomes usability, which is determined by various factors, availability of data being a significant one (Pozoukidou, 2014). Therefore, less sophisticated models that require few data could have better utilization prospects and consequently more practical value in the planning practice for emerging economies.

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Chapter 2

# Stakeholder consultation in freight transportation decision-making in port cities

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## Highlights

- Lack of engagement of all actors whose needs and goals should be represented in the models.
- Development of a stakeholders consultation framework ready to apply in emerging countries.
- Successful application of the framework in the port city of Thessaloniki, which is emerging from a financial crisis.

## 1. Introduction

Emerging market economies are progressing toward becoming more advanced and are faced with rapid growth and industrialization. To sustain their growth, they require efficient and reliable freight transport systems, safer transport services, and corporate practices aligned with policy and regulatory issues. The main goal of this chapter is to achieve better connectivity of their major hubs to benefit from globalization and deal with the increasing international trade volumes (Hirschinger et al., 2015) as new trade corridors and market development for freight transport services are enhanced. This, however, could lead to capacity inefficiencies and infrastructure constraints (Chen and Lee, 2014). To address such issues and improve the logistics-related network, a strategic freight planning framework is required. Strategy and policy decisions defining the targets in terms of network performance as

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well as fact- and risk-based network management (i.e., service level agreements and contracts) constitute the basis for developing structural and institutional changes that will allow a successful freight transport system (Hakanen et al., 2017).

Although freight transport operations are driven by private sector initiatives, the role of the public sector is crucial mainly in developing the proper regulatory framework, addressing social issues, and providing the necessary public transportation infrastructure. This role is even more critical in major cities of emerging countries, where the need for infrastructure upgrades is higher, making it more challenging to keep up with the pace of the changing environment. The changes in emerging market cities are related to the structure and needs of industries requiring goods movement activity, to the consumption pattern fluctuations due to transformations in population and economy, and to logistics processes and supply chains associated with the evolution in international trade, which strain the infrastructure capabilities. In cases in which a port is located within the region, additional challenges need to be addressed. These have to do, among others, with the port-related truck traffic, which is adding to the urban congestion and the scarcity of available land to accommodate increasing port-related activities. Such inefficiencies lead to increased cargo service time both on the land and the water side and raise the cost of imports and exports, hampering growth potential and undermining the competitiveness of the regional economy.

As emerging economies are becoming more important in the global trade and as global trade is dominantly carried by sea, ports and the port-related freight transport systems are of high importance. Ports constitute major connections to export markets and engines for increasing regional economic prosperity and development. At the same time, ports add to the overall city and freight planning complexity, as port cities have peculiarities regarding freight movements and face the challenge of balancing the demand for additional space for different activities (i.e., operational, industrial, touristic, etc.). To ease the pressure on the port–city interface, coordinate freight transport activity, and streamline decision-making, joint planning, integrated infrastructure development, and management and alignment of various actors within the context of a proper strategic freight planning framework are needed. Constructive dialog among key stakeholders with the aim of determining priorities and objectives in freight movement planning could provide a solid basis to overcome the difficulties derived from the interaction of port activities and urban growth.

Methods that promote the participation and interaction of both public and private sector actors are mainly suggested by the research community (Rohrbeck et al., 2015). The focus of this chapter is on how stakeholder consultation and public–private collaborative initiatives may support freight planning in an emerging market port city environment with the aim of achieving sustainable development. The policy challenges, previous experience, and the mix of commonly acceptable plans from different stakeholders are presented for supporting decision-making of public sector and industry.

An assessment analysis of the potential implementation of the proposed framework is presented along with the outcome of stakeholder consultation and collaboration for improving the current energy and environmental performance of the urban freight transport system.

## 2. Trends and challenges in port cities

Several strategies have been proposed to address freight transport and sustainability-related challenges in urban environments (Taniguchi and Russell, 2014). The rapid growth of freight volumes in port cities, especially in emerging countries, is creating a need to adapt these strategies and develop new ones for implementing energy-efficient and environmentally friendly urban freight transport measures in a more complex and integrated port city environment.

In most port cities in emerging countries, there are scarce, if any, environmental impact mitigation efforts or, in some cases, such efforts are limited to port activity and related traffic. The main reason is the lack of effective collaboration between municipalities and port authorities (Blanco, 2014).

Previous research on urban planning for port cities (Ducruet and Sung-Woo, 2007) presents how port activities are related to the urban freight transport services, revealing the importance of urban planning to overcome the problems derived from the interaction of port activities and urban growth. When relevant stakeholders are not actively involved, the operations become more complicated, and conflicting policy challenges may arise. Constructive dialog and setting of common objectives and priorities among private and public sector stakeholders have been recognized as a good practice to rationalize and achieve a sustainable urban freight transport system (Anagnostopoulou et al., 2017). Stakeholder consultation with the private sector joining forces with public authorities based on a synergistic strategy plays a vital role in exploiting growth potential. It assists in ensuring better communication and achieving broader acceptance of a freight transportation plan, avoiding a reduction of local embeddedness of ports in these countries (Merk, 2013). Moreover, it may constitute the basis for long-term development as better coordination, and greater openness could gradually engage international retail planners and financial institutions in supporting large-scale investments (Trappey and Kuan Lai, 1996; Hoskisson et al., 2013).

The proposed framework follows a cooperation scheme, attempting to provide substantial benefits (BESTUFS, 2007) and aiming to effectively contribute toward improving the cooperation between private and public sector stakeholders, especially in emerging urban areas. It exploits the rational planning approach of our previous work regarding sustainable urban logistics in port cities (Anagnostopoulou et al., 2017), which covers different planning aspects both at small-scale (micro) and large-scale (macro) levels (Fig. 2.1).

## 3. Trends and challenges in freight facility development

Based on the National Cooperative Freight Research Program report (Steele, 2011), freight planning in the public sector is supported by developing proper plans, setting regulations, and implementing several economic development initiatives such as tax concessions, loans, land subsidies or grants, utility rate reductions, access improvements, infrastructure grants, enterprise zones, foreign trade zones, inventory tax reductions, and customized training programs (Steele, 2011) to exploit opportunities of developing freight facilities. Developers often select developed countries, as they understand the benefits offered by freight facility development and participate in feasibility studies and discussions with industry developers. In recent years, however, there is a tendency for the private sector planners to focus on the reconstruction of the global supply chains by using locations in emerging countries as major freight system nodes.

Recent studies (Mattarocci and Pekdemir, 2017; Prologis Research, 2016, 2017) reveal that market proximity, road access, labor availability, costs (i.e., transport cost, real estate cost, and cost of labor), land availability, proximity to other modalities, regulation, and incentives are the main criteria that influence freight facility selection. Based on the Prologis Research (2016), two emerging countries (i.e., Central Poland and Turkey) ranked in the top 10 most favored locations for freight facility development although they lack in infrastructure. Moreover, in Europe, low-skilled jobs have been shifted to countries with lower labor costs (Taylor, 2015). As such, emerging countries constitute preferable locations for developing freight facilities (e.g., hubs, port inland terminals, intermodal logistics centers, etc.), as they offer low labor costs, high proximity to large markets, and land availability (WorldBank, 2017). On the other hand, a huge gap exists in regulatory issues and current incentives comparing to developed countries, which undermines the competitive advantage for their location.

In an effort to contribute toward these issues, this chapter presents a planning framework broadly applicable for stakeholder consultation to support freight transportation decision-making in emerging countries. From the

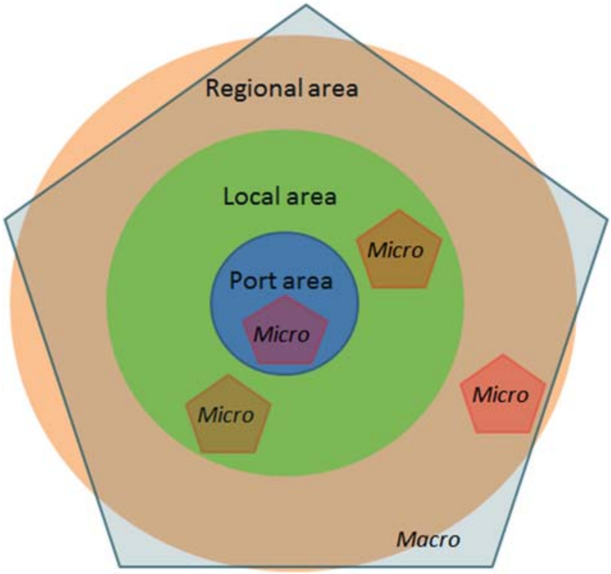


**FIGURE 2.1** Level of planning.

methodological viewpoint, the proposed framework introduces the "engagement of stakeholders" as a separate step in comparison with the existing frameworks of developed countries (Eatough et al., 1998; Taniguchi et al., 2012) in an attempt to enhance public stakeholders to provide tangible incentives that could smooth the implementation process and clarify expectations for the private sector.

In emerging countries, extra effort is required in order for public sector to understand the processes and drivers of private sector, thus resulting in a smoother and better-defined implementation process. The proposed framework also focuses on "setting common objectives" and "agreeing on commonly accepted priorities, among the various stakeholder groups" in an attempt to enhance the dialog among representatives of private and public sector, which will allow public sector to develop a vision and a proper strategy for freight projects in such way that conflicts are identified and mitigation actions are proposed.

The main contribution of the proposed framework lies in the aforementioned items (i.e., "engagement of stakeholders," "setting common objectives," and "agreeing on commonly accepted priorities, among the various stakeholder groups"), which clarify priorities and specify targeted criteria and indicators that support decision makers when determining actions for freight planning in emerging countries.

## 4. Framework for stakeholder consultation to support freight transportation decision-making

The proposed planning framework to be considered in urban freight transport decision-making for emerging port cities is presented in Figure 2.2. Considering the existing trends and challenges, a successful framework for supporting freight planning with the aim of achieving sustainable development should be based on the following interconnected building blocks:

1. *Engagement of stakeholders*, which includes workshops, focus groups, surveys, public meetings, and forums, roundtables, and panels.
2. *Setting common objectives* to determine the best acceptable plan for achieving a sustainable freight transport system in the area.

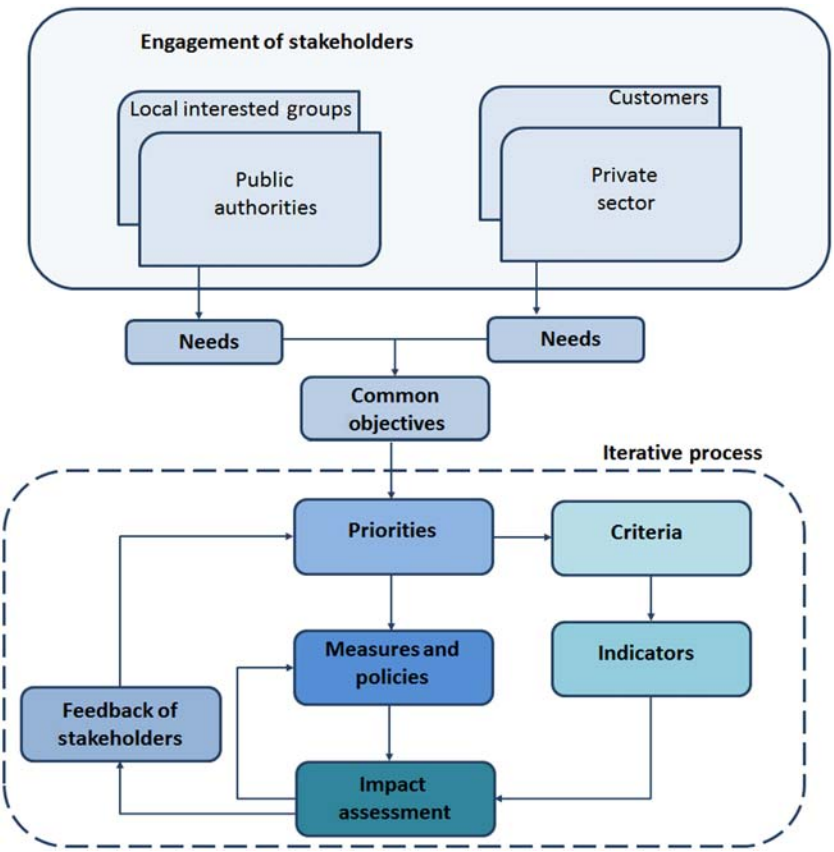


**FIGURE 2.2** Framework for stakeholder consultation to support freight transportation decision-making.

3. Agreeing on commonly accepted *priorities*, among the various stakeholder groups, based also on the special characteristics and issues of the area.
4. Developing *criteria* to assess the best acceptable plan for freight transportation in the area.
5. Use *indicators* to monitor and tackle the continuous evolution of progress being made and, in particular, the relevance, effectiveness, and efficiency of the implemented measures and policies.
6. Implement *measures and policies* that promote the commonly accepted priorities of the different stakeholder groups.
7. Perform *impact assessment*, which includes ranking techniques to determine the minimum, mean, and maximum values of the indicators used.
8. Receive *feedback from stakeholders* to support continuous improvement using information derived from the impact assessment.

The first step in the proposed framework involves the engagement of stakeholders to achieve common objectives between the public and private sector stakeholders, considering that a public authority's (i.e., Municipality, Regional Authority, etc.) main goal is to maximize social benefit and the private sector's (i.e., ports and industry) aim is to maximize profit and offer a high level of satisfaction to their customers. Fact sheets are necessary to inform the stakeholder representatives about the proposed freight transportation plan while their active engagement is required, through participation in workshops, focus groups, and other means of direct communication.

The output from this building block is the determination of the needs of public authorities as well as the needs of the private sector and their assessment, within the context of the emerging economy port city environment to derive common objectives. The identification of common objectives feeds the main iterative process, which involves the determination of priorities to set the basis for defining the corresponding criteria and indicators that allow monitoring and assessing the impact of the implemented measures and policies. On the other hand, measures and policies could be revised either based on the results derived from the indicators or in case the priorities change based on feedback provided from the stakeholders.

Relevant data and information are gathered related to each of the criteria and indicators. In consultation with the stakeholders, the different criteria are weighted and are applied for evaluation of the measures and policies. Data sharing among different stakeholders enables consistent and coherent information for evaluating implemented measures and policies and determining any required corrective actions. Data gathering and data sharing present significant challenges in freight planning. This is even more so in emerging economies not only because of the limited availability of structured data collection initiatives but also of the fast-changing environment, which requires more frequent updates of such initiatives.

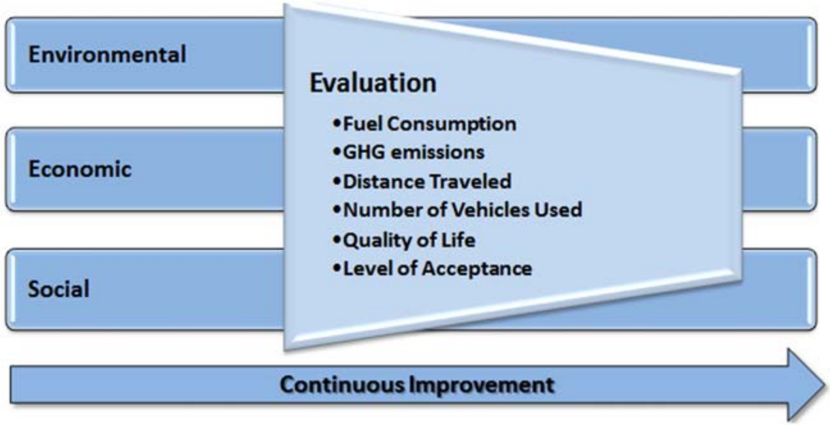


**FIGURE 2.3** Impact assessment approach.

The impact assessment approach (Figure 2.3) is used to evaluate the performance of the implemented measures and policies and addresses three impact areas: (1) environment, (2) economy, and (3) society.

This approach incorporates ranking techniques for determining the values of the indicators for each criterion. It provides a validation basis for the suggested action plans and supports the adoption of strategies for continuous improvement.

## 5. Empirical case study

The proposed framework for urban freight transport decision-making for emerging port cities is applied in an empirical case study regarding the freight movement of the Thessaloniki urban area in Greece. The city of Thessaloniki is located in Northern Greece, covering a land area of 138.847 $km^2$. With more than one million inhabitants and approximately 20% of the country's industrial activity, it is the second largest city in the country. Goods transport and delivery processes in the Thessaloniki urban area are complex because of the high levels of congestion, limited access to the downtown area, narrow streets, and restricted use of curb space. The port, which constitutes the main export port in Greece and the region, is located close to the city center. According to the General Transportation Study of the Thessaloniki metropolitan area, approximately 1,600,000 trips are made in the city. Almost 25% of these trips use the city center as their origin or destination (or both; GTS, 2000). Freight transport operations constitute a key component of the economic vitality of the area producing increased pollutant emissions and greenhouse gas (GHG) effects. As such, local and regional authorities as well as industry stakeholders should provide

**TABLE 2.1 Objectives for promoting sustainable urban freight transport.**

| Private sector | Public sector |
|---|---|
| Reducing energy consumption<br>Reducing traffic congestion<br>Improving the level of service of transport companies<br>Reducing operational expenditures<br>Increasing profit | Reducing energy consumption<br>Reducing traffic congestion<br>Improving air quality<br>Improving the level of road safety<br>Improving quality of life<br>Increasing the availability of infrastructure |

competitive traffic management decisions to offer improvements in terms of pollutant emissions reduction.

### 5.1 Engagement of stakeholders and setting common objectives

Regarding urban freight transport decision-making, the public sector aims to improve the quality of life for people and seeks suitable policies to gradually decrease energy consumption and positively influence the economic, environmental, and social conditions. The private sector aims to improve its effectiveness from an internal cost point of view but is not necessarily concerned with the external costs that are often generated in urban areas, such as increased traffic and negative environmental impacts.

In the context of the framework implementation, several interviews conducted with representatives of municipalities, ministries, chambers, and several transport industries to provide their feedback and share their experiences regarding decision drivers. Likert scale questions were used to measure attitudes that cover a range of opinions and provide respondents with prepopulated answer choices. A brief summary of the key objectives of private and public sector for promoting sustainable urban freight transport is presented in Table 2.1 based on the ranking questions answered by the stakeholders.

Certain objectives are common to both public and private sectors, although they derive from a different perspective.

### 5.2 Priorities, criteria, and indicators

The main priority for both public and private stakeholders is to minimize the energy consumption, which affects both operational and environmental impacts. For the trucks used in urban freight distribution, savings in fuel consumption (FC) could be translated into both operational and environmental savings that meet private sector profit maximization as well as public sector social benefit objectives. Hence, the empirical case study focuses on the assessment of trucks' FC and pollutant emissions along the main and secondary arteries. The indicators of proposed measure of effectiveness include FC and carbon dioxide ($CO_2$) emissions.

## 5.3 Measures and policies

Regional authorities decided to implement various operational and behavioral measures (i.e., off-peak hour and night deliveries, off-street delivery areas, and access control based on traffic/emissions zones). Toward this direction, the industry also made significant efforts in reducing the environmental impacts of freight distribution and relevant activities revealing their increased interest for achieving reduced emission profiles (mostly because of the impending taxation measures).

## 5.4 Impact assessment and analysis

According to the proposed measures assessed in this case, the public authority offers network-level traffic information to private transport companies, which, in turn, provide real-time data from their fleets to update the initial traffic information. Following the proposed framework, this empirical case study considers the traffic information provided by the Intelligent Urban Mobility Management System of the city of Thessaloniki (Fig. 2.4A) and uses real operational data [derived from the Controller Area Network (CAN) bus and devices installed on the trucks] from private transport stakeholders who provide freight transport services in the area (Fig. 2.4B).

Based on the traffic data of network models, a proper tool (computer programme to calculate emissions from road transport (COPERT) model) is used to estimate FC and traffic-related emissions without taking into account any further public and private stakeholder interaction in data sharing and information exchanging. A discrepancy is observed between the model-estimated values and the values from real-life conditions. When positioning data are integrated with spatial road network data to associate location, speed, emissions, and FC with road characteristics, the model estimates become more accurate. With continuous updates of real operational data from private transport stakeholders, the network model's ability to provide better estimates of emissions and FC increases.

Computational results are ranked according to the data received at a network level (i.e., traffic data based on network-level models) and at a vehicle level (i.e., real-time data from individual vehicles of private transport stakeholders). The FC and the corresponding $CO_2$ emissions are presented in Figs. 2.5 and 2.6. Comparing the absolute values of FC and $CO_2$ emissions, it is observed that network-level provides lower values for both variables over the entire network. However, a similar pattern is drawn between vehicle and network values.

The results shown in Figs. 2.7 and 2.8 present the comparison of FC and $CO_2$ emissions derived from vehicle data and network data. The dots in the scatterplot correspond to FC (Fig. 2.7) and $CO_2$ emissions (Fig. 2.8) calculated using the COPERT model for network-level estimates and obtained from the vehicle CAN bus and installed devices for the vehicle level. Both FC and $CO_2$ emissions seem to be underestimated at a network level, especially for the highway sections of the network, although there seems to be a better network-level estimate for average speed at a range of 30−50 km/h.

The results indicate that network data may be improved by calibrating specific parameters of the model based on data gathered from the operating vehicles (Figs. 2.7 and 2.8).

## 6. Results

The abovementioned analysis demonstrates how cooperative strategies for efficient transportation and logistics operations could be used by regional

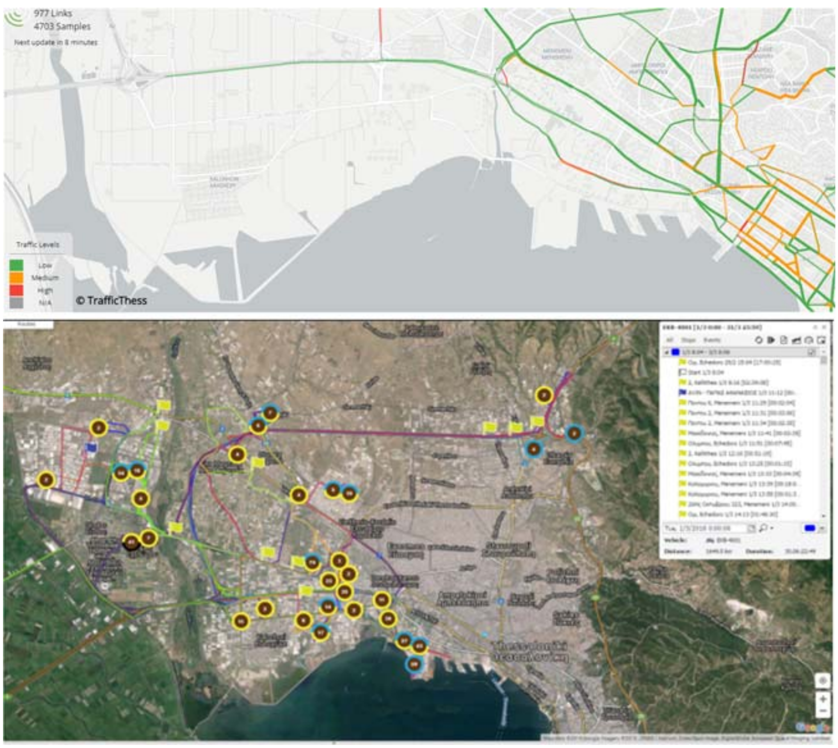


**FIGURE 2.4** Traffic data. (A) Traffic information from the Intelligent Urban Mobility Management System. (B) Traffic data from private transport stakeholders.

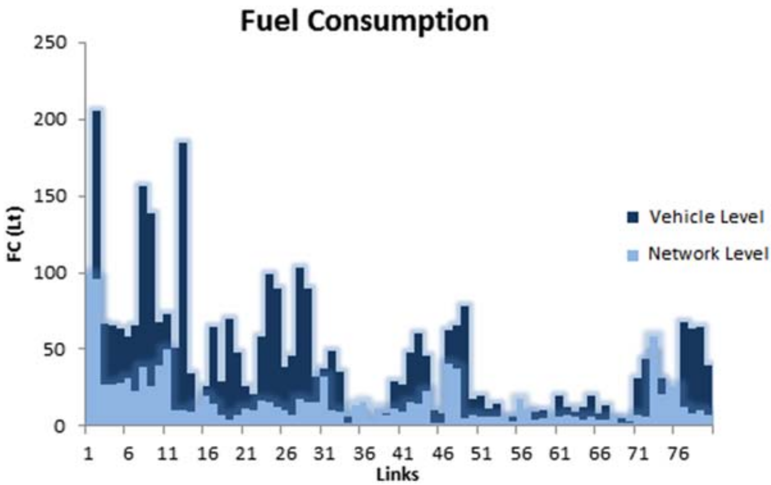


**FIGURE 2.5** Fuel consumption distribution among links.

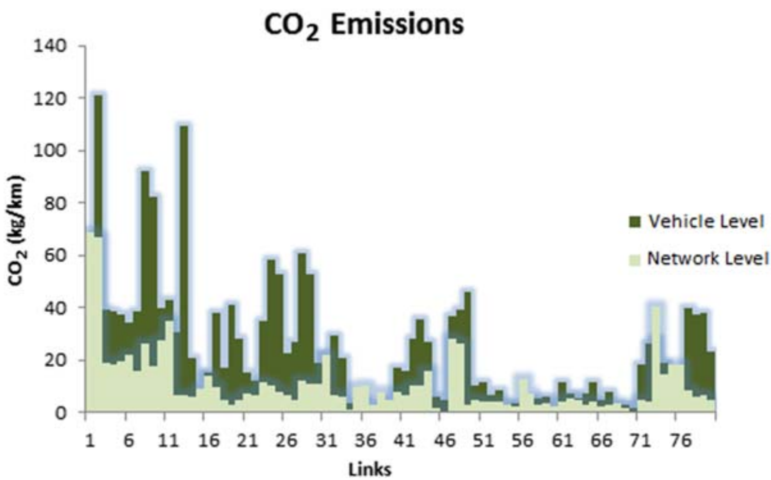


**FIGURE 2.6** $CO_2$ emissions distribution among links.

authorities and companies to provide competitive traffic management decisions evaluating efficiently current measures and policies.

The defined measures provide fleet operators with the ability to make assessments on the relation between their business activity and FC and $CO_2$ emissions. They also allow for direct evaluation of new transportation and distribution strategies that improve their operations by adjusting their driving patterns, evaluating driver profiles, improving scheduling and truck loading, and

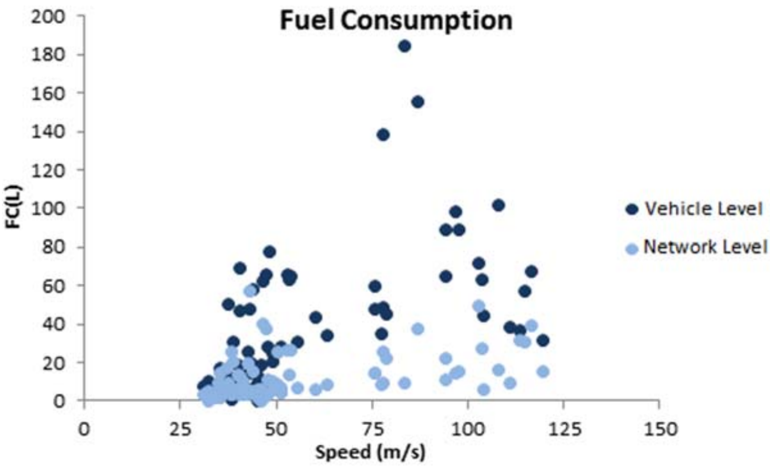


**FIGURE 2.7** Fuel consumption from network and vehicle observations as function of average travel speed.

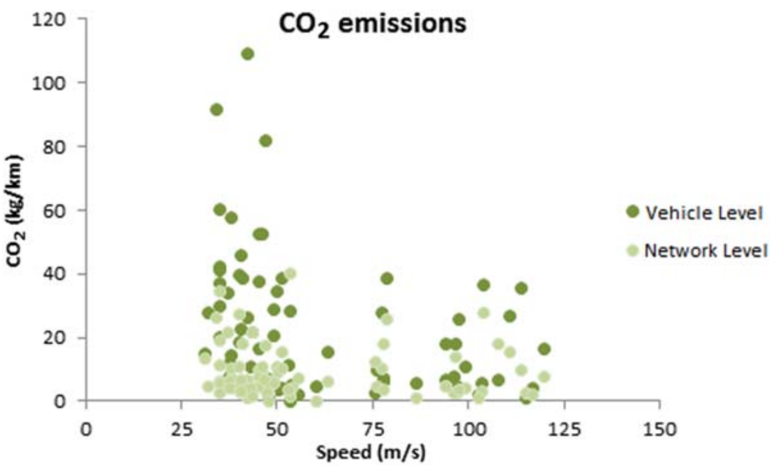


**FIGURE 2.8** $CO_2$ emissions from network and vehicle observations as function of average travel speed.

selecting the most appropriate itineraries. From the public authorities' perspective, infrastructure management and operations may be improved, producing overall traffic and environmental improvements at a network level.

The results of the analysis at both network and vehicle levels show that cooperation and data sharing among public and private stakeholders could improve the efficiency of urban freight transport and promote proper measures for reduced energy consumption and associated GHG emissions while enhancing economic savings and social benefits. Such collaborative initiatives may lead to more efficient and sustainable use of the existing transportation infrastructure without the need for major technology investment expenditures and costly data collection efforts, which are very important considerations, especially in emerging economies.

Based on the case study implementation of the framework, the key points for success could be summarized:

- Get the right stakeholders to the table
- Agree on the rules of engagement
- Manage expectations
- Use transparent and accountable goals
- Enhance flexibility
- Allow disagreement

Stakeholders from the private sector may have different level of experience in working with public authorities. This may affect the quality of their feedback as well as their ability to participate. Effective stakeholder engagement, definition of priorities, criteria, and indicators, as well as specification of proper measures and policies require specific skills. The absence of the right skills can hinder collaboration among stakeholders. Moreover, lack of success in the impact assessment process reduces the ability to learn and improve the implemented measures.

## 7. Conclusions and future developments

This chapter presents how efforts from different stakeholders should be coordinated to support freight planning that promotes sustainable development in a city. Capitalizing on previous experience and commonly acceptable plans from different stakeholders, a successful framework for supporting stakeholder consultation in freight transportation decision-making is proposed. An empirical case study for planning future measures and policies regarding urban freight transport is also presented. The cooperation and data sharing among private and public stakeholders are analyzed and shown to be promising for supporting freight transportation decision-making.

Although the analysis in this case study focused on demonstrating how the assessment of trucks' FC and pollutant emissions could be gradually improved and on providing more accurate data for defining proper measures and policies, the results provide a clear indication that sharing information between public or private sector leads to improved decision-making in emerging areas. This becomes evident from the empirical study results, which indicate that the proposed collaboration among private and public stakeholders results in gradually improved and more accurate traffic models for decision-making and more accurate routing information for transport operators. This leads to higher energy savings and emission reductions, which may translate to increased competitive advantage for the logistic companies and higher quality of life for citizens. Hence, a key challenge is to achieve collaboration among stakeholders and develop synergies even between companies from different sectors to allow data and experience sharing.

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Chapter 3

# Regional freight transport modeling: considerations from South America

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## Highlights

- Efficient integration of Latin American countries in the global supply chains.
- Development of freight transport models required "to think" on regional supply chain level.
- Evaluations of modeling need to inform effective long-term infrastructure decisions.

## 1. Introduction

South America is a region of enormous economic and social disparities. South American countries range from populations of 200 million (Brazil) to 3.5 million (Uruguay) and surface of 8.5 (Brazil) to 0.17 million $km^2$ (Suriname). The size of the markets and the level of development are various too. Although there are some members of the G20 and Organisation for Economic Co-operation and Development, there are others who have a gross domestic product (GDP) per capita of less than US $4000.

Nevertheless, there are several similarities in their economic structures, mainly given by the importance of the extraction of raw materials and low added value manufacturing. This production structure is export oriented, mainly to more developed countries, while importing industrialized goods.

The import and export flows influenced the development of transport networks in the region. The objective of the network was to develop the

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infrastructure to facilitate the flow of exports to ports, rather than to develop a network for integrating regional economies and societies, as part of its colonial legacy.

There is a strong dependency on road transport all over South America for the internal movement of goods. The main railway systems are those of Argentina and Brazil, although their modal share is relatively low. Regarding the intraregional trade, the largest share corresponds to sea trade (64% in volume and 46% in value), and a significant share is moved by road (30% by volume and 39% in value). There is some marginal transport by air, being of just 0.17% in volume (but 6.5% in value; Wilmsmeier & Spengler, 2015).

The appearance of global supply chain (GSC) and regional supply chain (RSC) reinforces the opportunity to take advantage of these regional flows to generate added value throughout the entire region. GSC reinforces the notion that competition is no longer between countries but between supply chains. Understanding and adopting the notions of GSC and RSC help to understand the new dynamics of the regional flows and how the transport systems can evolve.

Some actions can stimulate the GSC and RSC development in the region. Reduction of trade barriers among members, transport systems improvement, and regulatory cooperation and compatibility can be effective in doing so (Blyde, 2014). The results could help the generation and consolidation of RSC and participation in GSC.

Regional integration also plays a big role in the implementation of GSC and RSC in South America. Economic blocks such as Mercosur or the Pacific Alliance have proven to increase the trade among its members but have not changed the export profiles of the countries and the participation of intraregional trade (Desiderá Neto & Teixeira, 2012). Efforts to increase compatibility between regulations, foreign trade procedures, and logistical efficiency of international trade have been made in the last decades. Nevertheless, the experience in integration is still rather new.

More ambitious structures of regional integration have also been realized, such as the Union of South American Nations (UNASUR), which consists of all South American independent nations. (Currently, most structures of the UNASUR are not active. However, it is still a good example of regional integration initiatives.) Under this organization, several sectorial councils have been established with the participation of the ministries of the participants' nations. The most relevant action for transport infrastructure is the South American Council of Infrastructure and Planning (COSIPLAN), created in 2009. In 2011, the Initiative for Regional Integration of Infrastructure in South America (IIRSA) was created to support COSIPLAN with infrastructure development for boosting regional connectivity. The areas involved are transport, energy, and telecommunication.

However, since the integration processes is recent, many national interests tend to prevail over the regional ones. The internal transport policies of each country can collide with the global optimum of the region. This is especially true for “middle” regions (i.e., regions with passing flows from other countries).

To address, justify, and prioritize infrastructure investment, different transport models have to be implemented. Every model has its scope, objectives, strengths, and weaknesses, so it is logical that some adaptation has to be done to analyze different policies.

They vary across several aggregation levels, territorial coverage, data requirements, and institutional coordination needs. Areas can range from complex multinational corridors to localized country-level network revitalization. The objective of this chapter is to describe the models needed to address policy and infrastructure development in the context of regional integration in South America, discussing the various levels of aggregation and data needed. To do so, the framework proposed by de Jong et al. (2016) adapted to developing countries in Chapter 2 and with the overall description of models by de D Ortúzar and Willumnsen (2011), the main characteristics of the models are described. The models will be characterized with respect to its level of aggregation, data needs, and objectives and analyzed its compatibility with the objectives of the model.

The chapter will continue with Section 3.2, addressing different integration axes, choosing one of them for the modeling description, and exposing the general modeling requirements. Section 3.3 will address the particular example of infrastructure works between two countries with the binational tunnels under the Andes Mountains, and Section 3.4 will discuss the case of rail open access policy in Argentina to illustrate the difference between regional- and country-level policies. Finally, Section 3.5 will show the conclusions.

## 2. Regional development axis

As a consequence of the greater coordination among the different agents in the supply chain to reduce overall transport and transaction costs, the GSC and RSC emerge. It is evident that the elimination of tariffs will promote trade among the countries involved. Particularly in RSC, benefits are more significant because goods tend to cross the borders more than once. Moreover, regulatory and policy compatibility among countries in South America are fundamental for a better integration and for making the region more attractive. Both factors support the generation of new participants of the RSC by generating a more consistent regulatory framework (Blyde, 2014).

Infrastructure provision and adequacy plays an important role in the efficiency and attraction of GSC and RSC. In many cases, having a regional scope allows to identify priorities that can help the whole of South America to be more attractive. Without this regional perspective, the negotiation process between multiple countries becomes more difficult. In some cases, infrastructure improvements located in only one country have a positive impact on the whole region.

By the year 2000, the need for a greater physical integration among South American countries started to develop. Discussions on how to achieve this integration and how to overcome logistical and infrastructure bottlenecks can be traced back to the first meeting of South American presidents in Brasilia. With the presence of the 12 independent countries in South America (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, and Uruguay) and with the support of some international credit agencies, a process of integration started within the UNASUR. As a result, the IIRSA was created within the COSIPLAN with the objective to "impulse the integration and modernization of the physical infrastructure under a regional conception of the South American space" (Ministerio de Relações Exteriores do Brasil, 2000). The IIRSA–COSIPLAN had the following courses of action:

- Develop territorial participation methodologies, with the purpose of deepening and enriching the process of sustainable planning of the integration infrastructure, maximizing the benefits of the works, and reducing undesired outcomes.
- Engage in sectorial processes, with the objective of identifying regulatory and institutional barriers that prevent the development and infrastructure use in the region and to propose actions to overcome this. In all cases, coordinated actions among multiple countries are needed to get over the obstacles and promote the efficient use of infrastructure for the physical integration.
- Develop axis of integration, defined as multinational areas where natural, human, productive areas, and commercial flows concentrate.

## 2.1 Union of South American Nations development axes

South America has several production regions in different countries. Some of them are connected by the generation of RSC and the complementarity of raw material production and posterior manufacturing.

UNASUR and IIRSA identified nine regions that share production, territorial, and population links, denominated as integration axis. Overall, they include approximately 98% of the total surface of South America and roughly all their inhabitants. For each axis, there are several infrastructure plans oriented to boost regional integration. None of the axes cover an exclusive area of influence, as several regions overlap.

Of the nine regions, we will use three axes as examples to demonstrate some overall issues in the conception of the axes and common characteristics: the Amazonian axis, the Paraná−Paraguay waterway, and the Mercosur−Chile axis.

The Amazonian axis, being the largest of all, has a surface of 8 million km$^2$, corresponding to approximately 45% of the total surface of South America (but only 20% of the regional GDP; IIRSA, 2016a). It contains the whole Amazonian rainforest, the Amazonian river basin, Northeast Brazil, and the Pacific shore located adjacent to the east of the rainforest. Fig. 3.1A shows the conformation of the axis.

The biggest obstacle for integration is geographical. The presence of the rainforest and the Andes Mountains is a barrier to the movement and integration of goods along this axis. The production and consumption areas are located in the borders of the axis, close to the more populated urban centers in the coastlines of both oceans. Supply chains of the axis are divided into two different and independent zones with little integration or territorial coherence, forcing infrastructure plans not to be complimentary. Additional challenges of conserving biodiversity and forestall areas are present.

The Paraná−Paraguay waterway organizes itself around the subsidiaries that end in the Rio de la Plata River to flow into the Atlantic Ocean. It uses

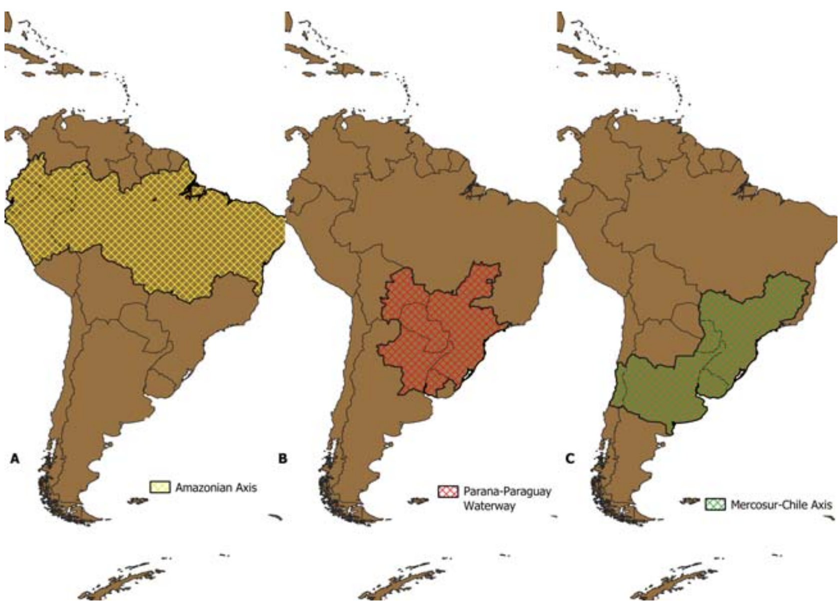


**FIGURE 3.1** (A) Amazonian axis. (B) Paraná−Paraguay waterway. (C) Mercosur−Chile axis.

the Paraná–Paraguay River as vertebral column that gives cohesion to the axis. Surface wise, it covers all of Paraguay, Southeast Bolivia, West of Uruguay, Southeast Brazil, and Northeast Argentina (IIRSA, 2016b). Fig. 3.1B shows the structure of the axis.

The waterway is more than 3,000 km long. It is mainly used to carry agricultural products to be transhipped in the deep water terminals down the Paraná River. Only 20% of the barges used for this purpose return with a full load (IIRSA, 2016b). Although it has the potential to capture part of the Western Sao Paulo state, the richest state in Brazil, this is unlikely because of the proximity to Brazil's big maritime ports.

Infrastructure development of this axis is mainly oriented to improve navigability in the waterway. This would have the effect to reduce the overall cost of the barges, to improve the level of service, and to increase fluvial market share.

The Paraná–Paraguay waterway axis, in contrast to the Amazonian one, has a strong territorial and production cohesion. The waterway is already used to some extent and has several RSC already functioning, such as Paraguayan soy being crushed in Rosario (Argentina).

The last axis to be described is the Mercosur–Chile (IIRSA, 2016c). The integration axis covers the main production regions of Argentina, Brazil, Chile, Paraguay, and Uruguay. It consists of the center of Argentina and Chile, Eastern Paraguay, the whole of Uruguay, and South Brazil, as shown in Fig. 3.1.

The Brazilian region contributes to 67% of the axis GDP, followed by Argentina with 21%. The main transport systems are the ones in the Paraná waterway (overlapping with the Paraná–Paraguay waterway axis) and the main road and rail corridors of the Mercosur. Sixty-two percent of the roads are asphalted, and 87% of the railways are operative in the region. Rail transport is exclusively for intranational transport because of the lack of gauge compatibility between the different rail networks.

Some of the RSC present in the axis are the aluminum recycling that starts in Chile and goes to Argentina and Brazil for processing. It is then sold to industries in Rosario, Buenos Aires, Cordoba (Argentina), Montevideo (Uruguay), Rio Grande do Sul, and Sao Paulo (Brazil). Copper is another example of raw material extracted in Chile and then transported to Argentina and Uruguay for manufacturing. Although these are parts of a supply chain, it does not mean that they are fully integrated. These flows are mainly unidirectional and hold little difference with regular exporting of raw materials (IIRSA, 2011). For RSC to exist, further processing and industrialization should be included with the movement of intermediate goods.

The three axes shown earlier have different characteristics that act as an example of the types of axes present in IIRSA–COSIPLAN. The Amazonian axis is big surface wise, has relatively low GDP, and shows little economic and geographical cohesion. The Paraná–Paraguay waterway axis is smaller with a definite economic area and similarity of industries.

The Mercosur–Chile axis is the most important in terms of GDP. It has significant trade flows across it, yet it somehow lacks some territorial cohesion because of the influence of origins and destinations on both oceanic shores. It also holds several challenges that are also present in other axes, such as lack of institutional coordination between countries, lack of data standardization, and little transport policy cooperation. Because of the importance of the axis and the transferability of its problems to other regions, the Mercosur–Chile axis is used for discussion.

As it is the biggest axis in terms of economic size, it also concentrates on several important transport infrastructure projects. Of the ones with greater impact are the intermodal terminals, gauge compatibility, railway revitalization, improvement, and building of binational tunnels between Argentina and Chile.

Binational tunnels are normally framed as part of bi-oceanic corridors between the Atlantic and the Pacific ports, meaning that, for example, production generated near the Atlantic shore would go through a Chilean port to reach Asia or west United States. Considering that the Chilean ports have a similar distance to Asian ports, the tunnels are more likely to work as a facilitator of trade within the axis rather than a corridor. This is especially valid for some provinces in Argentina.

The rail infrastructure projects tend to be in Argentina because of its central location in the axis and the large existing network. However, there are several interests deposited on these projects. Chile and Brazil may have a special interest in developing gauge compatibility because of the passing flows, whereas Argentina might focus on railway vitalization because of its greater impact on local logistics costs.

## 2.2 Modeling framework

The models needed for analyzing the integration issue illustrated by the three axes explained earlier should target a long-term macrointeraction among the economies. The models should be created to support decision-making for integrating the regions and prioritizing key infrastructure. The main characteristics of the models are described with the framework proposed by Jong et al. (2016) and adapted to the developing countries context in Chapter 2 and with the overall description of models from the study by de D Ortúzar and Willumnsen (2011).

It is likely that the institutional aspects of the models are the most difficult to overcome. By definition, the integration of a region involves the coordination of multiple countries. Consequently, an already big issue within one country becomes a bigger challenge. Responsibilities within a country can be divided into multiple areas, and they might not have a direct mirror in others. For example, some nations have a unique ministry that concentrates infrastructure development, whereas others have those responsibilities split among multiple ministries.

The result is a tougher flow of information between countries, limiting the synchronization of policies. Moreover, each country has their own regulatory framework, which is unlikely to be common because they address country-specific issues.

Stakeholders among countries differ too. Each country has different industrial profiles with different relative power among them. As a result, the countries may reflect conflicting interests to some policies, and coordination among them is difficult.

The confidence of the models may be affected by the multinational nature of the integration. Economic and political cycles are unlikely to be harmonized, deriving into the possibility of policy and investment shifts between countries during the time scope of the models. For example, Argentina, Brazil, and Chile have 4-year presidential mandates that start in different years, and Uruguay has 5-year terms.

## 2.3 Specifications

### *2.3.1 Level of aggregation*

The level of aggregation of a model determines the level of detail that it has. An aggregated model can have a big coverage in time and geography. As it brings together multiple effects, it tends to average out anomalies, making it stable for long-term models, where a lot of uncertainty is involved. Aggregated models capture the broad relationships between macrovariables and allow simpler forecasting.

More disaggregated modeling requires more details between the interactions among agents. It gives more information to the analyst at a higher cost of collecting data, modeling efforts, and more detailed interactions. When projecting future scenarios, the variables have a higher level of uncertainty and can bring bigger errors to the model.

For example, an aggregated model that relies on international commerce, GDP, population growth, and minimum cost paths will not be suitable for analyzing modal change or the interaction of RSC in the region. A model that takes into account logistics costs, production location, and modal choice behavior could achieve this, for instance, but it would not be able to forecast the increase of trade and freight movements in the long term. Although the latter is a much richer model, forecasting logistic costs over time are difficult, and the assumptions of the effect of new infrastructure are weaker. In addition, it probably assumes that the behavioral model is still valid over time, what it may be a difficult thing to assume in a 20-year model with unknown technological innovations. For the aggregated model, there are more established tools to forecast those variables, making it more comparable and compatible for long-term models.

The UNASUR axes were created to identify infrastructure priorities to boost regional integration. Although some interventions are trivial in terms of money and payback time, such as port access improvements, there are other interventions that are more complex and made to last longer. For example, tunnels are not projected for obsolescence, and the economic appraisal spans a period of over 30 years. The minor interventions can rely on smaller regions and more disaggregate modeling, but the larger ones should aim for long-term interactions among the regions.

However, it is not always a straightforward rule. Rail investments have long project duration (concessions can be of over 15 years) and might need to disaggregate behavioral modeling to justify investments. Understanding which parameters affect the modal choice to correctly reflect the rail's level of service is crucial for forecasting transport volumes correctly.

Regional integration is a matter of analyzing the interactions of several countries and regions. The level of aggregation of the analysis is an important matter to be analyzed. In general, freight transport regions need a certain degree of production and consumption homogeneity. Preferably, there should not be big differences in product volumes, and it is desirable to follow political disaggregation (e.g., provinces) to potentiate data compatibility.

The size (and quantity) of the transport regions also depends on the level of aggregation of the model. In general, the more aggregated the model, the bigger the regions will be. There is a trade-off between the size and detail of the network and the effort needed to collect data. For example, the zoning for the OD in Argentina (Benassi, 2015) consists of 123 zones, whereas the zoning used by the Brazilian National Development Bank (BNDES, 2008) uses 21 zones to represent the whole of South America.

Another aggregation consideration is the product types. Products grouping that responds to similar transport requirements helps to simplify the analysis and data collection. In addition, product groups, if disaggregated enough, can help to gain insights on complementarity/competitions of RSC.

### 2.3.2 Behavioral approach

Another element to take into account is the behavioral process of the model. Some approaches are more deterministic, and some are probabilistic. An example for the first case is all or nothing allocations to the shortest/cheapest route. These models are poor in the behavioral approach but help to understand potential cargo to be transported by a corridor.

A probabilistic approach takes into account the uncertain nature of choices and allows more than one route to be used. Depending on the data used for the estimation, it can have a behavioral background or just capture correlations between variables to reflect market shares. On the one hand, having a behavioral background is a more stable and causal relationships among the parameters and welfare measurements [e.g., value of time (VoT)] that can be used for cost–benefit analysis. On the other hand, they are much more data intensive and requires the data to be disaggregated per choice maker.

In general, it can be said that the models needed to address issues at an international level are aggregated ones. When multiple regions and expensive infrastructure are analyzed, the extent of the influence is of several years and thus involving large time frames into the models. This makes that the models overlook some local peculiarities and interactions.

## 2.4 Data

Some aggregated data on the zones are relatively easy to find or estimate. As most of the zones are an aggregation of provinces or nations, macroeconomic data (such as GDP and production volumes) are usually made available by the governments. However, some compatibility work should be needed because of differences in methodologies, especially between countries. Depending on product aggregation, comparable product types can be obtained independently from the country specification.

Although data on international trade are easy to find, it is more difficult to establish the origins and destinations. International commerce is well documented and publicly available, but information on where it is produced and consumed is not usually available, without detailed knowledge of the study area.

When incorporating modal change dimensions, as it would be the case for rail revitalization, information on the modal split is needed. Data availability for mode choice behavior historically has been a problem for mode choice in freight (Tavasszy and de Jong, 2013). In general, only aggregated data (generally at a regional level) are available of modal split at a regional level, limiting the size of the dataset for estimation. Moreover, accurate data on travel times, cost, and level of service are rarely found. Gathering revealed preference (RP) or stated preference (SP) data for behavioral models are also complex because of the large territorial coverage of the models, besides the usual problems of high collection costs, low response rate, and difficulty in identifying and contacting the respondents.

# 3. Regional-level models: binational tunnels

Binational tunnels under the Andes Mountains between Argentina and Chile is framed as a way of generating bi-oceanic flows, which are generated near one shore and exported through the other. These kind of infrastructure works have been in several infrastructure plans, boosted mainly by provincial authorities. The most common example the case is of Argentinian commodities generated in Buenos Aires or Cordoba with Shanghai or other Asian port as destination. This section discusses freight modeling issues over bi-oceanic corridors, first by analyzing the logic of those corridors over the example of binational tunnels and then illustrating the modeling needed to analyze its viability.

## 3.1 Context

For several reasons, the concept of improving access to Pacific ports is confused with the possibility of creating bi-oceanic corridors. This underlies the assumption that products originated near one ocean could be drawn to the other because they have a more direct export route. However, this may not always hold. The assumption is broken when considering the magnitude of maritime distances. As Fig. 3.2 shows, the distance covered by maritime routes between Valparaiso (main Chilean port) is larger than from Buenos Aires if the destination is Southeast Asia (from Hong Kong to the south).

Another source of error comes from not considering the relative importance of the inland leg of the travel. For the case of any product generated in the province of Cordoba (the main inland production center, relatively close to Chile), such as soy, with destination, Shanghai would have to cover a shorter distance than if exported through Rosario (20206 km vs. 21607 km). However, when costs are compared, it would be more than 1.6 times more expensive. Fig. 3.3 illustrates the example.

Although these estimations can be improved by considering the generalized cost of transport (e.g., through the VoT measurements), these rough calculations help to delimit the problems and influence of infrastructure investment, besides limiting the scope and efforts in modeling. The preliminary results from the valuations can rule out areas that, out of basic economic sense, would not be influenced by the tunnel. For example, there are some areas, such as the provinces that border the Andes Mountains that may see an increase in exporting opportunities with the binational tunnels, but it will not attract many products from eastern Argentinean provinces because of the fact that Atlantic ports have rather competitive shipment costs.

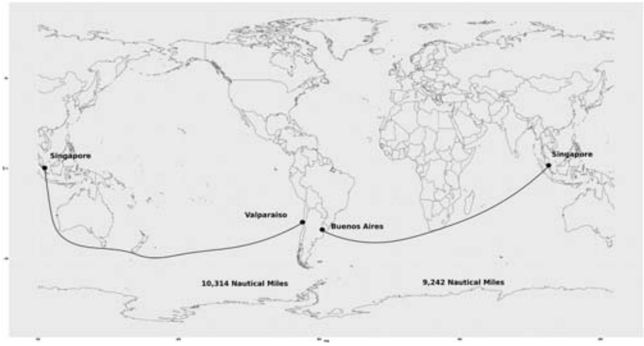


**FIGURE 3.2** Relative distance to South-East Asia ports.

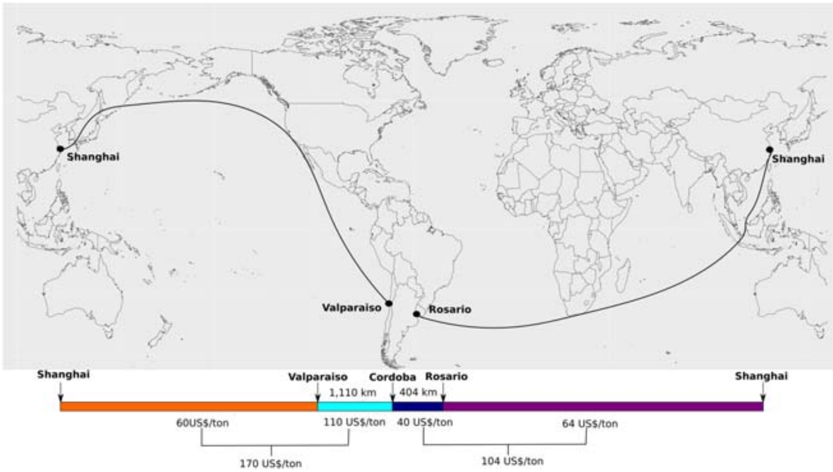


**FIGURE 3.3** Relative cost of sending soy to Shanghai from Cordoba.

## 3.2 Modeling framework

A model able to quantify the impact of a tunnel between Argentina and Chile is necessary to assess the infrastructure needed. Currently, the most used crossing point under the Andes Mountains is Cristo Redentor, near Mendoza City and Santiago de Chile. By connecting the capital of Chile and the most important industrial city in western Argentina, it receives and concentrates important flow of materials. Moreover, in winter because of the low temperatures, it is sometimes closed, incurring costly delays. This motivates the analysis for improving Cristo Redentor or creating new binational tunnels.

Such an analysis helps to reduce the regional coverage of the tunnel's influence. Having a tighter geographical focus reduces the effort involved in modeling. The regions to be covered consist of western and midwestern Argentina for newly drawn cargo and different regions of Chile and Brazil for existing freight flows. Chile and Brazil would be stakeholders because of the inclusion of passing flows (trade flows between these two countries), but it is unlikely that the tunnel would generate bi-oceanic flows.

## 3.3 Specifications

Spatially, the model has to be relatively aggregated. It has to reflect higher level of detail at the regions closer to the tunnels and higher level of aggregation at the regions further away, such as Brazil or coastal Argentina. In addition, its findings should be sufficient at least to evaluate the traffic for the first 20 or 30 years of the tunnel, so the level of time aggregation can be rather high.

As the flows follow international trade patterns, the overall trends of commerce are well tracked, and the expansion of the figures should be rather easy to adapt to this situation. The main difficulty in this case is to know the origin and destination, what can be done using local export, or production information. When analyzing the flows through Atlantic ports and that can be drawn toward Chilean ports, additional information on the final destination is needed.

The flows through the tunnels can be estimated by modeling the route choice. Because of the aggregation level of the model, a simple allocation with minimal cost analysis can be of good use because it allows the modeler to estimate the possible origins and destinations that are more likely to be drawn by each tunnel. An example of this approach in the context of international freight is presented for analyzing on binational corridors made in Brazil (BNDES, 2008). Although new initiatives have been proposed, such as the tunnel of Agua Negra, no detailed flow study has been found, besides the ones that fall under the issues detailed in Section 3.1 (COSIPLAN, 2017).

## 3.4 Data

The main type of data needed to calibrate the aggregated model for the binational tunnels is related to international commerce. In general, it is a stable and consolidated dataset created at official level. The challenge is to correctly decompose these international flow data into origins and destinations. Some common regressors for estimating international trade are population size, GDP, and past exports.

Some product flows in RSC are intermediate goods movements. For these products, official forecasts for the consumption of the final products of the supply chain can be used. With additional information on the inputs needed to get the final good (normally found in input−output tables), a successful estimation of intermediate goods can be made.

On the allocation side, the alternative networks have to be determined, over the costs (current and projected) and times. VoT measurements are useful to estimate the generalized costs, which can provide a better estimation than cost alone. However, these values are difficult to find in a Latin American context, so in case of unavailability, the VoT of developed countries can be used. There are still few VoT works in developing country context, so it is difficult to assess if any considerable bias is introduced by using it.

## 3.5 Limitations

One major challenge is coordination between authorities of different countries. The multiplicity of objectives, interests, and enforcement capability from national and provincial participants from Argentina and Chile are the most tangible barriers. National and provincial participants from Argentina and Chile with different interests are the most tangible barriers. Chile and Western Argentinean provinces might have a stronger interest in developing binational tunnels initiatives than the rest of Argentina because of the reduced costs of the existent commercial flows. Another issue are the long-term negotiations that are susceptible to changes in governments. Chile and Argentina have elections at different years, and each change of government tends to slow down the process and restart the negotiations.

In addition, there are many additional infrastructure plans in Argentina and Chile that can influence the flow of goods. For example, transport infrastructure and policies in Argentina have a direct influence on the destination choices of cargo generated in Argentina. The following Section 3.4 presents an example of such policies in detail with the example for the rail modeling in Argentina.

## 4. Country-level modeling: railway system in Argentina

Argentina, besides being one of the most important economic areas in the Mercosur−Chile axis, acts as a middle region for flows between Brazil/Uruguay and Chile. Consequently, some inefficiencies of the Argentinian transport network are replicated into these flows. Although the former countries have a strong interest in improving infrastructure to reduce logistic costs, Argentina gives more importance to local functioning of the railway network rather than optimizing for passing flows. This section discusses the historical and current reasons for Argentina to adopt a rail open access system and the models needed to assess this policy.

### 4.1 Context

Argentina's modal share is, as in the rest of Latin America, dominated by road transport. Of all the goods transported, only 5% go by rail (ITF-UNSAM, 2012). In the case of agricultural products, it raises to 14%, measured in transported tonnes. This has led to a relatively high cost of transport in every sector of the economy compared with other countries of the same dimension as Argentina. Some authors (ITF-UNSAM, 2012; Schwartz et al., 2009) claim that this is caused by the relatively short distances connecting exporting/manufacturing areas. In distances under 300 km, truck tends to be more competitive because of the relatively high impact of the road leg of the trip (transporting from the harvest fields to the railway plant). However, there is some evidence that with a higher level of service (frequency, capillarity, and reliability), rail can gain market share even in short distances (Tapia et al., 2019).

The rail network is mainly port oriented because it was built with the objective of moving agricultural production for export. The national network has not been centrally planned, so in the overall network, there are three different gauges, depending on the geographical characteristics of the terrain, which decreases the interoperability of the network (Raposo, 2014).

After reaching its largest extension of 44,000 km in the fifties, the functioning railway network length started to fall until it reached a minimum in the 1990s, when it was privatized. After the privatization, rail recovered volume, but not network length. Nowadays, the network consists of 25,500 km of railway, of which approximately 18,300 km are operative. In the year 2018, nearly 19 million tons were transported at an average distance of 485 km (9000 tons-km).

The network was divided into six rail lines to be outsourced. Between 1991 and 1993, five of them were successfully transferred to the private operators for 30 years. Among the obligations of the private parties were to pay a fee for the infrastructure use and rolling stock and to invest in the modernization and improvement of the network. Fig. 3.4 shows the current operating network.

In the beginning, the volume transported grew, as the level of service improved but at a slower pace than expected. This shows flaws in the demand estimation models of the tender, making the concessionaries to fail in complying fully with their obligations. Besides the loss in operating lines, there is a severe degradation. The opportunistic behavior was also allowed because of deficiencies and late applications of the regulatory framework for the privatization (Raposo, 2014). The situation led to a renegotiation that eliminated the fee and gave greater flexibility in the investment requirements. However, this did not happen in every case, as two of the concessions have been revoked and are currently operated by a public company because of the high level of deterioration of the infrastructure.

After the Argentinian crisis of 2002, when all the economic activity suffered, the volumes carried by the railroad recovered, but at a slower pace than the total amount transported, causing the rail market share to decrease even further. This has been more noticeable in the agricultural sector, which historically was an important niche in the Argentinian rail market.

Besides the uncertainty of the regulatory framework, the economic crisis and the optimistic demand forecasts are the major causes of the current state of the market share of the railway. The acquisition of railway lines by companies to transport their own products is another factor to be taken into consideration (ITF-UNSAM, 2012). Although they are obligated by contract to accept the third-party cargo, this does not always work. Two examples are worth mentioning in this matter. The first one is about the network South of Buenos Aires, of Ferrosur, which is currently operated by the same economic group that owns a quarry in the region. Therefore the main product transported is minerals at the expense of agricultural products, which is also present in the district. Consequently, the grain volumes transported by rail are marginal, so the links that were not important for quarry did not get enough

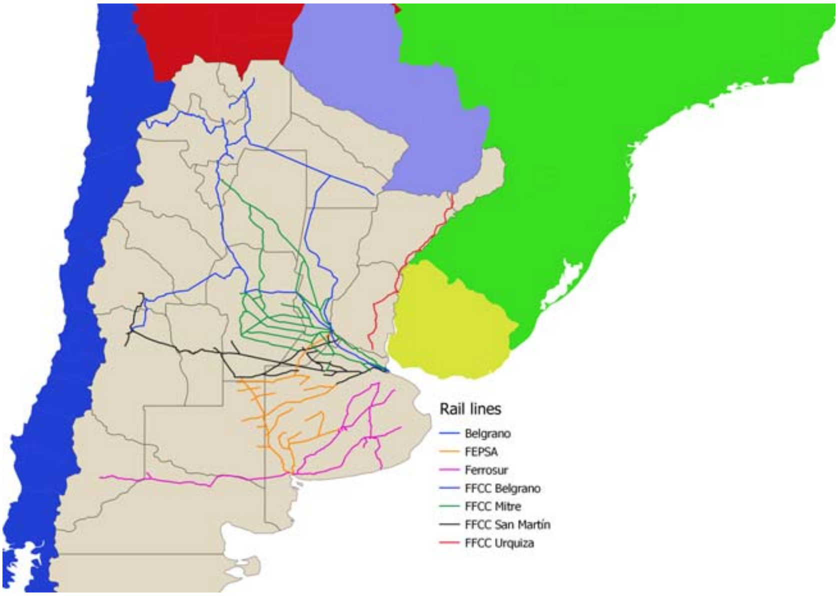


**FIGURE 3.4** Rail network in Argentina.

investment to continue to operate, and the rolling stock priority was not allocated to this product.

The second integration worth mentioning is of the railroad Nuevo Central Argentino (NCA). NCA has a big presence in the heart of the agricultural production area, and it is owned by one of the biggest seed crushers of Argentina. Although some products of other companies are accepted, there is no incentive in pursuing additional cargo and thus sharing its competitive advantage. There are reports suggesting that inconvenient loading time windows and relatively high prices are offered to competitors.

In both cases, the organizations that took over the rail lines have a strong interest in moving their own material and optimize their logistics. This does not imply that they do not want or are not interested in transporting extra cargo, but given the low investment in rolling stock and infrastructure, they privilege their own products.

The lack of effective regulation has resulted in a lowered level of service, absence of incentives for looking for new clients, and outdated infrastructure and rolling stock, which can be considered a recurrent issue in developing countries. Vertical integration combined with the low acceptance of cargo from other companies is a mixture that has implications in modeling because it will break most assumptions about the availability of alternatives, especially for choice models. Not knowing beforehand who has the option of choosing rail can bring bias to the parameter estimates because the model will confound the effect of no availability with a nonpreference of the alternative. Additionally, there is an asymmetry on the service information available obtainable for modeling, such as fares and travel times. It is likely that companies that own rail lines have a different tariff than other shippers.

To promote the participation of more companies and to expand the rail market share, an open access policy is under evaluation. The idea is to separate the providers of the infrastructure from the operation as an attempt to increase the participation of several providers. This way, this separation would facilitate the appearance of new service providers and make it feasible for other companies to carry their own goods and to capture other smaller loads (ITF-UNSAM, 2012).

## 4.2 Modeling framework

To evaluate the effectiveness of an open access policy, an ad-hoc model should be used. The models currently under use in the Ministry of Transport of Argentina consist of detailed O-D matrices and some aggregated overall estimation for potential cargo to be transported by rail (Benassi, 2015). The model consists of several methods for obtaining and updating O-D matrices and for assuming a likelihood of being transported by rail depending on the product characteristics and distance of the travel. This likelihood of adopting rail are coefficients that determine the potential volume that the rail could attract. The main limitation is the lack of behavioral background involved in the definition of these coefficients, resulting in little responsiveness of demand toward changes in the network, such as improvements in reliability, frequency, and lower travel times.

Regarding the organization of the model, institutional aspects of it should be easier to overcome. Although the coordination of multiple authorities (such as the Ministry of Agriculture, the Ministry of Mining and Energy, the Ministry of Economy, and the Ministry of Production) and data from multiple sources is needed, the Ministry of Transport has the greatest responsibility in policymaking and enforcement of the open access. The Ministry of Transport has also under its influence (although with some independence) the control agencies.

## 4.3 Specifications

When evaluating infrastructure use, specifications not only for the demand but also for the supply models must be considered. The model should accommodate the mutual interactions of supply and demand characteristics to address the impact of policy scenarios, to understand current and future operators' incentives, and to assess the compliance with the objectives of the policy. Network use and open access regulation are some of the possible objectives of the model.

A model of this nature is complex because of the multiple interactions between demand and supply side. From the demand side, modal shift has to be studied in detail to assess the potential demand for the railway at different levels of service. This has to take into consideration potential pricing strategy reactions of the road services. The model should be suitable for forecasting of a behavioral nature.

From the supply side and to consider the feasibility to attract private interests or to evaluate public participation, supply side modeling should be incorporated. Cost models that consider different levels of service (with interaction with demand side modeling) are preferable to consider the trade-offs between cost and potential remuneration. Pricing strategies for infrastructure use could be simulated in this stage. These types of models that reflect interactions are also important to understand the incentives of the operators (how to maximize own profit) and if they are aligned with the objectives of the public sector policy (maximize social benefit). With the application and simulations of the model, several policies can be tested to make the public and private sectors' objectives to be compatible.

Cost−benefit analysis for public sector investment can also be included. Quantifying benefits that go beyond cost savings are important to analyze up to what extent the public sector is willing to invest money or subsidize rail using. Some of these benefits could be lower truck-related accidents, emission reduction, road congestion, and noise, among others (Havenga, 2015).

## 4.4 Data

Regarding data collection, the demand side is likely to be more difficult. If a behavioral framework is preferred, disaggregated data have to be obtained. To do so, there are mainly two sources: RP and SP. RP consists of actual choices made by shippers, whereas SP consists of declared choices in hypothetical scenarios.

RP is generally preferred because of the better representation of reality. However, there are some drawbacks, such as failing to accommodate new or unavailable alternatives and to obtain the actual parameters used by the choice maker. In chapter Y (the chapter on tax revenue data processing for modeling), a discussion on how to obtain RP data from nontraditional sources is made.

SP can solve these issues by allowing the modeler to create the choice scenario. By also being able to show more than one choice task per respondent, data collection is easier. However, the hypothetical nature of the situations makes models estimated exclusively from these data unsuitable for forecasting. To overcome the weaknesses of both sources, models with combined RP and SP data can be estimated (Hensher, Rose, & Greene, 2008).

In addition, data on current and projected flows are needed too. For the Argentinian case, the Ministry of Transports estimates OD matrices for different products (Ministerio de Transporte de la Nacion Argentina, 2017b). This matrix is periodically updated, but it has a greater focus on flows created in Argentina, having an overall aggregated view of the road trade between Brazil and Chile. Although the Brazil–Chile flows might not be as significant as flows between Chile and Argentina, they can still cause the infrastructure to be under dimensioned.

For the supply side model, data on the network are needed. Road data are widely available in multiple formats, but rail data are outdated. Most sources do not consider the current operational status of the tracks. In that sense, the Ministry of Transport is making a significant effort to have reliable data on the network status. In addition, the ministry has also created rail cost models (COSFER) for the operation of the railroad that can be used in the model (Ministerio de Transporte de la Nacion Argentina, 2017a).

The COSFER has been a 2-year project that generated a cost model that depending on the terrain, operational speed, volume, and other operational variables, it estimates the operational, maintenance, and investment costs (if renovation of rail tracks is projected). The validation of the model has been done with interviews with the different rail operators.

## 5. Limitations

Regarding the confidence level of the model, some challenges arise with the trucks companies and unions power. They have shown in the past a high reaction to the introduction of the railway by adjusting prices and generating nonmarket barriers, such as blockage of rail loading plants. A difficult thing to consider in the models is the impact of social issues derived from the potential losses of jobs in the trucking sector. Argentina, as many other countries in South America, has a large number of families that depend on trucking incomes to survive, meaning that the loss of jobs in the sectors will have an important social resistance.

Other issues that can interfere with the applicability of the results of the model are the regulatory assumptions. The open access law was enacted in 2015, but it has been neither effectively regulated nor enforced. The final regulation of the open access could be the result of the model by generating and comparing the reaction of current rail operators and potential new ones in different scenarios. However, to capture these behavioral responses is a complex matter, even if the model explicitly models the responses.

Besides the already mentioned lack of access to data for infrastructure, level of service, network, and rail tariff, there is the issue on how to model rail availability in an area (i.e., who has the possibility to ship by rail). Behavioral models are particularly sensitive to this issue. If an attractive alternative is available and not chosen, its attributes will be interpreted as "undesired" in the modeling process. This could result in a bad model specification, wrong signs of the variables, or low significance of important variables. To solve this issue, assumptions on availability have to be made, with a potential bias on the model.

One dimension of the limitations of the model is how to quantify the impacts of the infrastructure improvements on the region, such as the generation of new volumes of trade generated. The models that are used focus on the transport system of Argentina only. Consequently, the results and applications of the model are confined to the country because of not only the assumptions needed for extrapolation and transferability of the projects but also the effects of the assumptions on other models.

For example, as the Argentinian network is heavily port oriented, it is more likely that those links receive a better overall level of service. Consequently, Atlantic's ports hinterland increases, reducing traffic across the Argentina–Chile border. The inverse is also true; some flows that would naturally have come to Atlantic ports (either by truck or rail) could be drawn toward Pacific with the construction of binational tunnels.

Besides the effect of the open access in ports hinterlands, the considerations of other countries in the policies are not necessarily taken into account. Chile and Brazil, for instance, have strong interest in developing infrastructure to reduce the costs of entering and moving within Argentina, which would involve better roads and intermodal terminals. This, although it does not contradict the open access policy, is not purely aligned with its objectives.

## 6. Conclusion

Regional integration in South America has not been a straightforward process. There are plenty of institutions with their own objectives and regional coverage. The focus case for integration in this chapter has been on the axes proposed by COSIPLAN-IRSA in the context of UNASUR. Although this may not be the main institution that drives this integration, the axes show the general ideas that the integration of the region have.

Three different axes have been described. The Amazonian axis covers a large territory with lack of production flow logic, something that Paraná–Paraguay waterway axis has. In the middle and as a representative of the axes that have some level of production flow logic and holds most of the integrational challenges, the Mercosur–Chile axis is presented.

Several transport projects are available to boost integration along this last axis, some of them at a regional level and other exclusively at a country level. Regardless of the territorial coverage, they share similar challenges, such as multinational interest, agencies and cooperation issues and interests, and problems in data generation and availability.

Some projects with regional-level impact can be tested with simple yet effective models to reduce and focus the scope. Binational tunnels between Argentina and Chile are examples of this. With simple relative distance analysis, the use of these tunnels to help ports on one ocean attract cargo closer to the other shore is rejected in most cases.

Nevertheless, high institutional challenges are expected because of the international nature of the intervention.

At the country level, Argentina's policy on rail transport is relevant because of the passing commodity flows it has. The intention to reregulate the rail market with an open access policy to increase its market share demands complex modeling. Behavioral modules with interaction with supply side modules may be considered to define and model concession and investment plans. Moreover, the development, implementation, and update of the model should not have many institutional issues, and there are several nonmodel-related challenges such as truck unions and current operators' interest. A challenge to be addressed from the regional point of view is the inclusion of other countries' interests in the definition of the rail policy.

Overall, the models needed to address policy issues at a regional level are difficult to develop and implement. For the simpler models that can be solved with aggregated and not so detailed modeling, there are multiple coordination challenges among the countries. Other models, such as national-level models, may have an easier coordination between stakeholders but have a more complex and detailed modeling.

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Chapter 4

# A methodology for disaggregated freight demand modeling in emerging economies

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## Highlights

- Limited data on the spatial and sectoral composition of national freight transport demand and lack of understanding of emerging economy macrologistics contexts.
- Need for the specification of data-driven model structures to forecast disaggregated national demand for freight transport.
- Development of a freight demand modeling approach that spatially and sectorally disaggregates national freight flows in emerging economies.

## 1. Introduction

Inefficient transport systems increase input costs and constrain national growth potential and international competitiveness (Jankauskaite et al., 2013). Pressure on freight transport networks and related services is expected to intensify because of continued growth in consumption (fueled by population growth, urbanization, and a growing middle class) (Ivanova, 2014), exacerbated by transport infrastructure capacity challenges (Müller et al., 2012). Improvements in logistics efficiencies and infrastructure capacities can alleviate these pressures with concomitant beneficial impacts on the

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broader economy. Improved logistics can increase domestic technical efficiency (i.e., it enables higher outputs with a given amount of inputs and technology; Coto-Millán et al., 2016) and lead to rising per capita incomes (Zaman and Shamsuddin, 2017), whereas, from a trade facilitation perspective, improved logistics reduces trade costs and facilitates global value chain integration (World Bank, 2016).

Yet, as far as can be ascertained, logistics performance is not tracked as a regular macroeconomic indicator anywhere in the world. This can be attributed *inter alia* to the absence of quantitative methods to enable logistics decision-making on a national scale (Tavasszy and de Jong, 2014). Huber (2017) emphasized the "major need for effective and more accurate tools to support public sector decision-making" within the freight transport sector. Quality data, transformed into objective, comprehensible, and useful intelligence, are essential for national governments and institutions to accurately plan, fund, and evaluate development activities (Beguy, 2016).

Advances have been made in demonstrating the statistically significant relationship between logistics performance and the level of international trade (refer, e.g., to studies by Hausman et al., 2005, 2013; Portugal-Perez and Wilson, 2012), frequently pointing to the quality of infrastructure and technology, port efficiencies, and customs procedures as key enablers. The inputs for these analyses are typically existing economic and logistics performance indicators, including the World Banks' Logistics Performance Index (LPI) data, World Development Indicators (WDI), and World Economic Forum (WEF) data (refer, e.g., to studies by Su and Ke, 2017; Ekici et al., 2016). LPI data are survey-based and focus on international trade performance, whereas the WDI and WEF indicators provide insight into the health of a representative basket of indicators for national economies. The positive correlation between logistics infrastructure investment and economic growth (through strengthening the capital production factor) also receives research attention (refer, for example, to studies by Fedderke et al., 2006; Pradhan and Bagchi, 2013; Song and Van Geenhuizen, 2014).

The abovementioned research is invaluable for benchmarking purposes, informing policy development, and highlighting aggregate areas most in need of logistics improvement. The underlying data, however, do not allow in-depth analysis of the spatial and commodity characteristics of freight transport itself to facilitate targeted investments and efficiency initiatives over the medium and long term to enable the management of transport as a strategic national resource (Tavasszy and De Jong, 2014). Existing empirical literature on freight demand modeling focuses on aggregate trade flows (Ivanova, 2014), single industries (Da Silva and de Almeida D'Agosto, 2013; Ottemöller and Friedrich, 2017), or single geographies (De Oliveira and Pereira, 2014), which hampers an understanding of the role of transport in national and regional economic competitiveness and sectoral development (Mačiulis et al., 2009).

More than three decades ago, Kojima (1982) and Raza and Aggarwal (1986) appreciated that aggregate freight flow analysis does not reflect the diversities in the regional and sectoral production or consumption processes in an economy. Freight flow modeling should be based on an understanding of underlying economic activity, as freight transport is both an outcome and an enabler of economic interactions (Tavasszy and De Jong, 2014; Stinson et al., 2017).

The systematic collection and analysis of these data are, however, still a challenging task, especially in emerging economies (Rantasila and Ojala, 2015). In addition, the development of models to analyze and interpret these data on regional and sectoral levels is often prohibitive because of the complexity and resources required. These challenges limit the potential for objective, data-driven policy development and investment prioritization to enable logistics' role in supporting national socioeconomic growth ideals. Established freight demand models (FDMs) in developed economies cater to the information availability and infrastructure requirements of mature economies. Similar to macroeconomic interventions, simply applying these established models to emerging economies frequently leads to policy failures, as they do not take into account the data availability and unique characteristics of emerging economies (OECD, 2017).

Typical challenges to freight demand modeling in emerging economies are as follows:

- Data aggregation: Statistical agencies often summarize data (e.g., on production or consumption) into unusable aggregate formats that render it of little value to disaggregated freight demand modeling and frequently modelers are required to go back to the source to recode data. This challenge can be overcome if the value of accurate disaggregated data is understood by data custodians.
- Fixation on "recipes": There is a desire to apply models from existing literature to reduce risk and time spent. However, often modelers' limited application experience results in the inability to adapt models to local data and resource availability, as well as a failure to interrogate outputs within the national freight and broader economic contexts. This hampers modeling efforts, and therefore, the availability of modeling outputs, which, in turn, hampers future modeling endeavors as the value of data-driven decision-making cannot be demonstrated.
- Limited funding: This is related to the aforementioned challenge. To gather sufficiently disaggregated data from a sufficiently large sample to enable extrapolation to national freight flow aggregates through surveys

or interviews can be a costly and time-consuming exercise. Funding is frequently not obtained or efforts are abandoned prematurely.

- Timing: Country-level challenges (such as delays in ports or poor LPI scores) increase the urgency for national logistics strategies. Often, however, quick-fix strategies are required by senior policymakers, lacking sufficient data, which can lead to lengthy, verbose documents with limited application possibilities. In most instances, spending the time and funding on building sufficient datasets to inform an understanding of freight flows, scenarios, and required investments will yield significantly better results.

This is summarized by Beguy (2016), as political economy challenges relating to a lack of autonomy and stable funding for national statistical systems; misaligned incentives contributing to inaccurate data; dominance of donor priorities over national priorities; and limited access to and usability of data. He advises (1) an increase in funding, in conjunction with appropriate incentives for data provision that is accurate, unbiased, relevant, timely, disaggregated, and widely available; and (2) the development, empowerment, and support of institutions that can produce these data.

To at least partly address these challenges, this chapter describes an approach to facilitate the development of disaggregated national FDMs in emerging economies by leveraging existing data sources. The methodology is customized for two major emerging economies, namely, South Africa and India. (In chapter 8, the application of the model outputs to inform macrologistics decision-making is illustrated.) In the context of this research, national freight demand modeling refers to the development of models that estimate the total volume of freight movements within a country. This, therefore, includes all domestic flows (road, rail, and inland waterways where applicable) as well as international trade (i.e., cross-border trade and maritime imports and exports). Spatial and sectoral disaggregation of such a disaggregated national FDM is essential for the model to have meaningful applications to address challenges within the nation's freight flow landscape (Havenga and Simpson, 2018).

In the next section, a succinct description of key macrologistics challenges faced by the two selected emerging economies is provided. The literature review summarizes the purpose of and current approaches to disaggregated national FDMs, identifying the need to develop a viable approach to this type of modeling for emerging economies. Subsequently, the methodology is presented, followed by concluding remarks.

## 2. Macrologistics challenges facing the emerging economies selected for this research

Gross domestic product (GDP) growth for South Africa averaged 1.7% between 2011 and 2018, down from 3.5% between 2001 and 2010, with 0.7% projected for 2019. These growth rates are in sharp contrast to those in India, the fastest growing major economy in the world, which averaged around 7% for almost the past two decades (albeit expected to slow down to 6% in 2019; IMF, 2019). One of the challenges, therefore, for South Africa is to unlock logistics efficiencies to support economic growth, whereas India is faced with the challenge of creating infrastructure capacity to support its unprecedented growth rates. Both countries, however, also face severe socioeconomic challenges, *inter* alia extreme poverty and significant spatial and income inequalities. The prioritization of logistics interventions should, therefore, be based on addressing these multifaceted challenges.

South Africa spends 10.9% of its GDP on logistics, compared with India's 13%. Although it compares well with its other BRICS partners (Brazil at 11.6%, Russia at 16.1%, and China at 14.5%), it is higher than those of developed economies with, for example, the United States ratio at 8%, Germany at 8.8%, and Hong Kong at 8.5% (Armstrong and Associates Inc, 2018). These disparities hinder the realization of the potential of logistics to contribute to domestic socioeconomic goals. In the World Bank's 2018 LPI, a measure of country-level efficiency of international trade supply chains, South Africa was ranked 33rd of 160 countries and classified as one of the top-performing upper-middle-income economies, whereas while India was ranked 44th of 160 countries and classified as one of the top-performing lower-middle-income economies (World Bank, 2018). Although these achievements are remarkable, both countries have significant infrastructure backlogs with long inland transport distances and long distances to trading partners, compounded by the economic and social challenges mentioned earlier. The development and application of disaggregated national FDMs are expected to aid in addressing these challenges, as the quantification of the national freight flow landscape will highlight the key areas of concern and enable targeted policies and investments.

## 3. Literature review

Four decades ago, Van Es (1977) described the purpose of national freight demand modeling based on key outcomes, namely, to:

- Inform policy measures related to (1) improved transport infrastructure, (2) optimal modal competition, and (3) impact analyses of various transport policy alternatives;
- Estimate the composition of future freight transport demand to inform modal and investment requirements and enable cost−benefit analyses for infrastructure investment decisions (e.g., modes, hubs, and ports); and
- In the long run, leverage the understanding of future requirements and subsequent infrastructure investments to influence the spatial location of production and demand patterns.

These outcomes have been echoed recently by Banomyong et al. (2008), Tavasszy and De Jong (2014), and De Jong et al. (2016).

Outcomes relating to sustainability and the decoupling of transport and GDP, while already analyzed in the 1970s (Meadows et al., 1972), have only relatively recently been included in national-level transport discussions. The project "Tools for Transport Forecasting and Scenario Testing" (TRANS-TOOLS), the European Union–level freight policy model, for example, defined the policy focus of systemic freight transport analysis in terms of informing sustainability, intermodality, and decoupling (Korzhenevych, 2012). Delfmann et al. (2010) called for a reflection of the United Nations (1987) triple-bottom-line measurement, that is, balanced economic, ecological, and social goals, in logistics systems to support sustainable development goals. The latter is more realistically attainable when the policy debate is shifted from emotional and rhetorical arguments to an objective, data-driven process as a precursor to the policy development process (Duffy, 2017; Wendling et al., 2018).

The purpose of the disaggregated national FDM (and the related cost models that will be discussed in chapter 8) is to provide this data-driven impetus for the national freight transport policy cycle in emerging economies.

To develop multicommodity multiregional national FDMs, an econometric modeling approach is required (Havenga and Simpson, 2018). Econometric models attempt to identify and analyze cause-and-effect and correlative relationships between total freight demand and its drivers. The need for these models has been understood for decades, but the practical application has been lagging. Kresge and Roberts (1971) emphasized the importance of coupling the macroeconomic environment, industrial production, final demand, and freight transport on a network in a freight demand model. Van Es (1977) described the key outputs of such a model as volume and geographical composition of domestic and international transport by commodity group, the current and estimated share per transport mode for different scenarios, and the capacity per mode. Fosgerau and Kveiborg (2004) showed that estimating future freight transport requirements from aggregate production lead to overestimation of transport growth because of the economic shift to less transport intensive industries. This supports sectoral disaggregation in national FDMs to improve the accuracy of transport volume estimates and forecasts.

There are two main approaches to develop the spatially and sectorally disaggregated freight flow data required for these models: a survey approach and a demand-side approach.

A survey approach involves estimating the characteristics of the total freight market through analyses of the responses to a commodity flow questionnaire distributed to a representative sample of freight logistics stakeholders, combined with other data sources. A limited number of countries (e.g., the United States and Sweden) conduct regular commodity flow surveys (CFS) as the basis for their FDMs. The most well-known FDMs are SAMGODS (the Swedish model) and the Norwegian model, which both use the Swedish CFSs conducted in 2001, 2004–05, and 2009. The models for mode and shipment size choice that are being developed for the European model TRANS-TOOLS3 use both the CFS 2007 from Sweden and the Experience of Care and Health Outcomes survey from France (conducted in 2004) as databases for freight flow estimation (De Jong et al., 2016).The US CFS is conducted every 5 years; the latest available data are for 2012 with data for the 2017 CFS (conducted in 2018) expected to be available mid-2020 (United States Census Bureau, 2018). Comprehensive CFSs are extremely resource intensive and still require significant analysis post-survey to estimate the total freight market. In addition, survey-based research suffers from a number of recognized challenges, such as sampling biases and nonresponses or partial responses (Kockelman et al., 2009), as well data continuity challenges because of time lapses between surveys and changes in scope (Bergquist et al., 2016).

A demand-side approach develops freight flows based on interactions between supply and demand as informed by macroeconomic input–output (I-O) tables, which describe interdependencies between industries in terms of intermediate inputs, driven by developments in final household demand (OECD, 2019). The country-level multisectoral I-O framework was developed by Leontief (1986) in the 1930s, based on the theory of Keynes, who postulated that production is determined by consumption, that is, market equilibrium, expanded to multiregional or spatial I-O models in the 1950s (Ivanova, 2014). The growth in international and cross-border trade in the latter part of the 20th century peaked interest in the spatial disaggregation of national accounts to improve planning. This led to a growth in the adoption of I-O analysis for planning, forecasting, and general impact analyses, especially in emerging economies (countries such as Brazil, China, Nepal, and the Philippines developed I-O models for these purposes). There are also developments within I-O modeling to enable the incorporation of a wide array of spatial and sectoral data to reduce uncertainty and improve applications, so-called hybrid I-O models (Lahr, 2016). Müller et al. (2015) (for Germany), Alises and Vassallo (2016) (for Spain and the United Kingdom), and Lin et al. (2016) for Singapore, confirmed the use of I-O models (or subsets thereof) to improve the understanding of the link between economic activity and freight transport.

As far as can be determined, there are no regular national CFSs in emerging economies that provide sufficiently comprehensive spatial and sectoral views on freight transport flows. In South Africa, a number of surveys were attempted during the 20th century. The surveys were discontinued because of low response rates and limited macroeconomic applicability (Havenga and Pienaar, 2012). A demand-side model is, therefore, proposed as the basis for freight demand modeling in emerging economies driven by a multiregional and multisectoral I-O model of the economy because of its comprehensive nature and resulting application possibilities. The volumetric outputs from the I-O model are then used in the flow model to ensure both internal alignment between these models and alignment with national I-O aggregates.

The specific contributions of this modeling approach are that:

- A complete view of economic activity (supply and demand) is developed on the most detailed geographical and subsectoral/commodity level that is available in the economy under question. This is made possible through the hybrid (or triangulated) data collection and modeling approach as described in the next section, using the specific datasets available in each economy. Through using data sources from both government and industry sources, the most accurate data are collated;
- Freight flows are then derived from this complete view of economic activity, resulting in useful, practical outputs that can be segmented according to various geographical and commodity combinations to inform specific questions, for example, relating to investments in ports, corridors, or logistics hubs or to inform or guide spatial developments through analysis of forecasted freight flows;
- The strength is in the *disaggregated* analysis made possible, as will be illustrated in chapter 8;
- Despite the onerous data requirements, this is a cost-effective approach for the level of detail rendered and the resources required (specifically, people, travel, and communication costs). No primary research such as electronic surveys, interviews, or truck intercept surveys are required. These types of data inputs are typically very resource intensive (and therefore costly), with relatively low response rates if not face-to-face, or dependent on the knowledge and understanding of the interviewee (Jessup et al., 2006). The application of data extrapolation techniques is also required to obtain aggregate national data, which are especially challenging if response rates are low.

This modeling approach supports the criteria for data-driven decisionmaking namely comprehensiveness of data, consistency of definitions, and credibility of outputs (Eberstadt et al., 2017), as the disaggregated nature of the modeling enhances transparency and possibilities for both input and output data interrogation. The model outline is discussed below.

## 4. Methodology outline

The overarching process and key data sources of disaggregated national FDM in emerging economies are indicated in Fig. 4.1 and described in subsequent sections.

The basic approach is to develop detailed spatially and commodity-level disaggregated data for each supply and demand component, as reflected in Eqs. (4.1) and (4.2), the aggregate of which reflects total national supply and demand; and subsequently modeling commodity-level freight flows between the disaggregated origins (supply) and destinations (demand) (O-Ds).

$$\text{Total demand} = \text{Intermediate domestic demand} + \text{Final domestic demand} + \text{Exports} \tag{4.1}$$

$$\text{Total supply} = \text{Production} + \text{Imports} \tag{4.2}$$

This approach renders standardized outputs that are comparable across countries, even if improved or continuously updated, irrespective of various data inputs. These standard outputs are as follows:

- Spatially and commodity-level disaggregated supply and demand data;
- Resulting freight flows with the primary parameters of origin, destination, commodity, volume, and transport mode.

The disaggregated national FDM for India is discussed in detail in Simpson et al. (2016) and Aritua et al. (2018) and South Africa's FDM™ in Havenga (2013).

## 5. Hybrid input data sourcing and apportionment to supply and demand tables

The hybrid input data sourcing includes gathering data from existing data sources that can be completely or partially related to freight, with an origin, destination, volume, or commodity attribute. The level of geographical disaggregation for each country is unique and based on the most detailed level available within that country. This is usually at a standardized district level within a domestic economy, whereas all trade entry and exit points, namely, major air, sea, and land border posts, are shown separately to aid analysis.

South Africa's FDM™ data are populated for 354 domestic districts, expanded to 369 geographical areas by distinguishing the eight border posts between South Africa and neighboring countries and South Africa's seven ocean ports. India's data are populated for 637 domestic districts, expanded to 672 geographical areas by distinguishing 30 of India's ports and five neighboring countries (Bangladesh, Bhutan, Myanmar, Nepal, and Pakistan). A display of the districts per country is provided in Fig. 4.2, whereby each

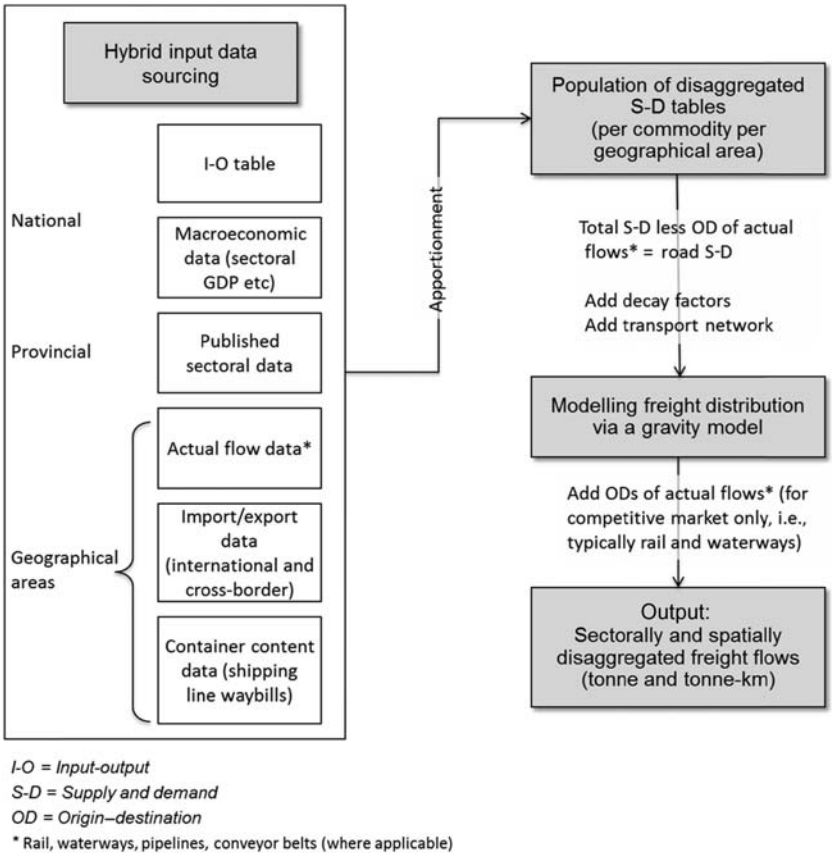


**FIGURE 4.1** Modeling process for disaggregated national FDMs (Havenga and Simpson, 2018).

district is outlined in the same color as other districts per province in South Africa, and per state in India.

All freight in an economy should be collated into useful commodity groups. For both South Africa and India, commonly referenced commodities in microeconomic analysis are used. Commodities that are of strategic importance to the country being treated will also be identified and modeled separately. An example of this is the coal sector in South Africa, where the FDM$^{TM}$ will distinguish between export coal, domestic coal, and power station coal for electricity generation because of each subsector's unique flow characteristics. The commodity groups identified for South Africa consist of 20 agricultural commodities, 30 mining commodities, and 33 manufacturing commodities, whereas the commodity groups identified for India consist of

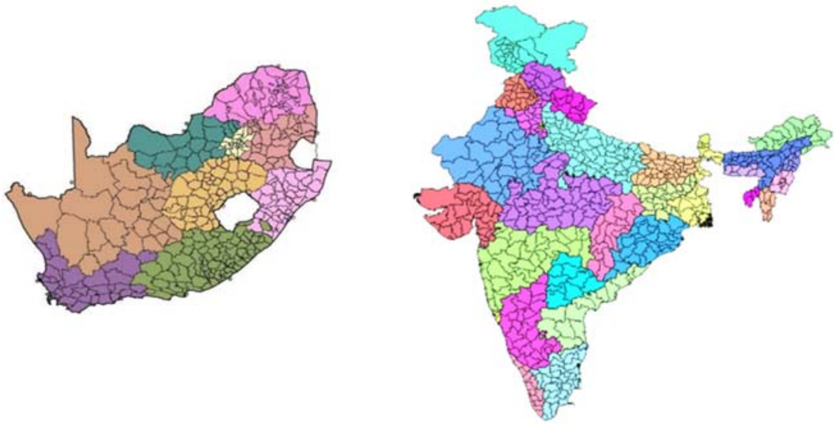

**FIGURE 4.2** Geographical disaggregation—display of districts per province in South Africa (left; created by authors) and per state in India (right; Aritua et al., 2018). (With regards to India, refer Fig. 4.3 for a depiction of the disputed areas between India, China, and Pakistan).

nine agricultural commodities, five mining commodities, and 17 manufacturing commodities.

Where sufficiently disaggregated data are not available, higher level collated commodity groups become a starting point until further detail is developed. However, it is important to note that modeling solely on the level of the major transportable economic subsectors, that is, agriculture, mining, and manufacturing, would provide little value in the modeled outputs, as commodity-specific flows need to be understood for infrastructure investment (such as logistics hubs) and collaborative freight transport solutions (such as intermodal transport). Similarly, sufficient geographical disaggregation is required.

Research is conducted on a commodity-by-commodity basis using data from government departments, key transport nodes such as ports and borders, industry associations, databases populated and maintained by private companies, general industry reports, and news articles.

The data sources are, therefore, a hybrid of sources with various levels of detail, all collated to a uniform geographical level and commodity grouping, for supply and demand. Some of these data sources are typical national-level statistics such as national I-O tables and GDP statistics. These are usually readily available and are common reference points in any model alignments when multiple sub-models or data development methods are uitlized. The gathering of these data often overlaps with alternate sources of data, and data sources should be aligned or ranked according to reliability and accuracy to derive the best data to use. Where possible, a disaggregated I-O

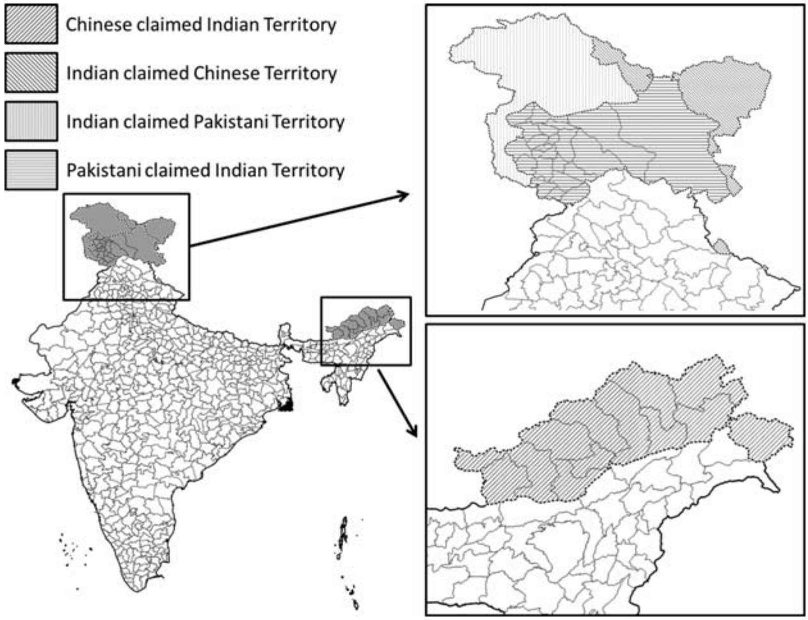


**FIGURE 4.3** Disputed borders between India, Pakistan and China[1]

table could be updated for freight which will further enhance the disaggregated national FDM capabilities. Wherever actual data are available, this should always be used in place of modeled data. As more data sources are combined, the resulting gap that the model needs to fill decreases. Correlation with a national I-O table or other macroeconomic aggregates ensures that traffic volumes are not over- or under-reported (Liu et al., 2006).

Where data are not available on a regional level, secondary keys are used for apportionment. For example, to apportion private consumption expenditure on motor vehicles, keys such as household income, electricity consumption, and car ownership are used, whereas intermediate demand for coal is estimated from the production of electricity (based on the known location of coal-fired power stations). These secondary keys are then integrated using weights. The total consumption or production of a commodity is then apportioned on a regional basis; however, in many cases, there is no need to use this method because geographically disaggregated production data are available.

[1] For the purposes of India's FDM the broad definition of regions (i.e. all disputed areas) was used to facilitate modelling accuracy. The authors are impartial to border disputes.

From a freight transport point-of-view, transport mode operators can provide the first in-depth view of freight movements in the country. Unfortunately, road transport is the largest and most fragmented mode and is often the unknown area. Both South Africa and India have one predominant rail operator, handling roughly one-fourth of the freight in each country. The national railway operator in each country keeps very detailed data on the freight moved on rail, and this is a primary input for freight modeling, as known flows provide insight into average distances traveled, areas of production, and interrelated commodities in product supply chains where raw materials might be moved on rail, and road might move the finished product. Similarly, ports and government revenue authorities can typically provide detailed data on freight handled at ports and border posts. The primary sources of actual data are given in Table 4.1.

Although this hybrid input data sourcing process seems onerous, it is facilitated by the Pareto principle:

- Eighty percent of India's supply and demand tons are contributed by 12 commodities. If coal, which contributes one-fourth of total tons, is excluded, 13 commodities contribute 80% of the remaining tons.
- Eighty percent of South Africa's general freight tonnes are contributed by 20 commodities.[2]

In the first iteration of a disaggregated national FDM, the population and verification of disaggregated data are resource intensive. However, for subsequent model refinement, the base exists and is updated and refined.

In comparison, the collection, data cleanup, analyses, and processes to extrapolate sample data from surveys to the universe are also time- and funding-intensive and might not yield the aggregate results required, especially where response rates are low.

Examples of the hybrid triangulation process for two commodities (citrus and wheat) are provided in Textbox 1 and Textbox 2 respectively below.

[2] General freight excludes the following flows: bulk, dedicated commodities of power station coal (transported on conveyor belts); the ring-fenced rail flows of export coal, export iron ore, and export manganese; coal flows on conveyor belts to South Africa's synthetic fuels plant; and crude oil in pipelines. These data are included in the aggregate model, and forecasts are important for planning purposes; however the data are readily verifiable, and the commodities have existing, dedicated transport solutions. In addition, "stone and aggregate" is excluded because it is typically a very short distance movement of mostly construction aggregate that is challenging to quantify, and transport is extremely dispersed. For the hybrid approach, it is important to research general freight Pareto commodities in detail.

**TABLE 4.1 Sources of actual volumetric data to populate disaggregated supply and demand tables.**

| India | South Africa |
|---|---|
| • Prowess database: intermediate demand, mining and agricultural production, and beneficiation of products at specific locations throughout India over multiple years<br>• Handbook of horticultural statistics (Ministry of Agricultural Statistics) and mining statistics (Ministry of Mines)<br>• Import and export data per port, per cargo type and major commodities (some ports such as Haldia and Kolkata has disaggregated data per commodity and even O-D states), as well as bulk data per port and name of a local company for coal and iron ore<br>• Containerized volumes with contents were obtained for all major ports<br>• Aggregate import and export data per commodity for India (to serve as control).<br>• Freight rail movements (on commodity and O-D level)<br>• Production volumes for agricultural and mining commodities per state or district from IndiaStat<br>• Industry reports for key commodities<br>• National trade data<br>• General industry reports and news articles | • The Abstract of Agricultural Statistics and crop estimates published by the Department of Agriculture, Forestry and Fisheries<br>• Agricultural crop data (Western Cape Department of Agriculture)<br>• Mineral industry statistics (Department of Mineral Resources)<br>• Data from industry associations (e.g., Perishable Products Export Control Board, the South African Sugar Cane Growers' Association, the Chamber of Mines, the National Association of Automobile Manufacturers of South Africa, and the South African Petroleum Industry Association)<br>• Disaggregated volumes and tariffson O-D level for rail, conveyor belts, and pipelines<br>• Import and export data (ports and border crossings)<br>• Container content data from shipping line waybills<br>• National trade data<br>• General industry reports and news articles |

O-D, origin-destination.

Textbox 1 Hybrid data usage—Planning for quay wall container capacity in South Africa (based on Van Eeden, 2018)

A unique component of South Africa's disaggregated national FDM™ is the development of a content-based quay wall container framework to enable port planners to base container volume forecasts on economic activity, not on historic container trends or other broad indicators such as aggregate GDP growth. This is important to reduce the volatility typical in container forecasts globally. It is also imperative, especially in the case of emerging economies, that sufficient infrastructure is created to facilitate the success of domestic beneficiation initiatives through access to export markets. The comparison of various datasets for citrus exports in 2014 is provided as an example of triangulating different data sources:

- The South African Revenue Service (SARS) reported 1,797,308 tons of citrus exports in 2014, of which 115,470 tons were transported via air and cross-border road, so 1,681,836 tons were exported over the quay wall.
- The Citrus Growers' Association (CGA) reported that 150,260,989 cartons of 15 kg citrus were exported in 2014, that is, 1,728,915 tons in total (quay wall, air, and cross-border; a 4% discrepancy with SARS totals)—which is deemed acceptable for this level of modeling.

Transnet National Port Authority (TNPA) reports bulk citrus quay wall volumes of 239,417 tons through all ports. Subtracting this from SARS quay wall totals amounts to 1,442,419 tons of citrus in containers. This triangulation is important, as, for example, SARS commodity-level data can be misclassified due to e.g. skills challenges, whereas CGA data can underestimate actual tons as excess fruit can be loaded in boxes to compensate for moisture loss of fruit during exports.

This tonnage-based total can, therefore, be used for forecasting based on trends and expectations in the industry and then reverted to container totals to enable more accurate container demand forecasts. This is especially impactful when commodity-based analysis is aggregated across all container transport, especially for manufacturing exports where the bulk of current and future transport is taking place, but where levels of containerization also need to be understood to account for both shifts to containers up to a certain ceiling and growth in underlying commodities.

To confirm this, Van Eeden (2018) validated the content-based container quay wall projection against a GDP-multiplier quay wall projection. The GDP multiplier was based on historic container growth versus GDP growth (an aggregate approach confirmed through a literature review). It is important to note that both the GDP multiplier forecast and the container model forecast proposed, use the same GDP forecast as underlying input. However, the content-based model uses this on the disaggregated level per commodity and then adds up the containers over all commodities back to a total per port and for the country. The content-based model was found to predict the container volumes more accurately: the content-based model's error remained within 7% of the actual recorded volumes over the 5-year forecast, whereas the GDP multiplier overstated capacity by more than 20% over the same 5-year horizon.

Textbox 2: Hybrid data usage—spatial disaggregation of wheat production for South Africa's FDM™

The South African Abstract of Agricultural Statistics is published annually by the Department of Agriculture, Fisheries and Forestry South Africa (2019) and reports total wheat production per province annually. South Africa's Western Cape province populates a spatial dataset indicating where crops are planted. Using this spatial dataset, the arable area per district for wheat production (and other agricultural commodities) is calculated (Western Cape Department of Agriculture South Africa, 2017). This provides the proxy to split the wheat produced in the Western Cape across the Western Cape's 42 districts. For other provinces where a spatial dataset is not available, the district split of provincial tons is informed by desktop research and verification with large industry players. Further triangulation of wheat supply is made possible through the availability of TNPA and SARS import data, which provides supply (imports) where ports or border posts are located.

For wheat demand, the locations of major grain millers are obtainable from the National Chamber of Milling. The capacities of these mills are used to verify wheat demand per district in the I-O models. TNPA and border post data provide wheat export data (i.e., demand for the districts where ports or border posts are located).

Actual rail data are captured and provided by South Africa's rail freight operator, and these data are used as minimums per district (i.e., the rail origin is a minimum supply for the district where the rail station is located, whereas the rail destination is a minimum demand for the district where the rail station is located)

The input into the supply and demand tables is, therefore, dynamic and will change from economy to economy, depending on data sources. Horridge et al. (2005) introduced the use of published sectoral statistics to improve national I-O table data. This hybrid data collection approach is also evident in the freight models of Norway (Hovi et al., 2013), Germany (Müller et al., 2012), Belgium (Mommens et al., 2017), and the United States (Fullenbaum and Grillo, 2016).

The basic approach can be summarised as:

1. Determining supply and demand per commodity group from authoritative sources (such as government departments or industry associations) and verify against other available information (such as trade data, production data, and rail data);
2. Researching the most likely spatial disaggregation factors/splits for both supply and demand (based, e.g., on actual data, arable agricultural land, location of production facilities, and population distribution);
3. Disaggregating supply and demand based on the triangulated information;

4. Aligning disaggregated supply and demand per district to the supply and demand minimums (using imports and exports per port and border post and rail data, as minimums).

The input data for the flow modeling is created by subtracting the origin and destination data of known flows from the supply and demand data, respectively. The balance of supply and demand data is then modeled as road flows via a gravity model, as discussed in the next section.

## 6. Modeling freight distribution via a gravity model

The most commonly used approach to distribute freight between regions is the gravity model (Ivanova, 2014; Arbués and Baños, 2016). The gravity model assumes that bilateral trade flows are directly proportional to the volumes of supply and demand of the regions under consideration and inversely proportional to a measure of transport resistance. Distance is a common measure of transport resistance, as it is an objective, readily available variable. Road cost components, such as diesel consumption and truck wear-and-tear, also typically have a linear relationship with distance (Martinez-Zarzoso and Nowak-Lehmann, 2007; Giuliano et al., 2013). A distance-decay function describes the attraction value between origins (supply) and destinations (demand) (Smith, 1970). The decay parameter determines the slope of the decay function. Distance decay varies from one commodity to another, based on its nature and utility. Low-value, bulk commodities generating a transport demand disproportionate to their value tend to have a sharp rate of decay, whereas for higher value commodities, the impact of distance is smaller, suggesting low decay parameters (UK Department for Transport, 2002). These commodity characteristics translate into two distance decay functions, namely, (De Jong and Van der Vaart, 2010):

- An exponential function representing quickly declining distance decay, that is, resulting in very little or no long-distance flows (mostly used for bulk commodities or homogenous goods); and
- A power function representing more gradually declining distance decay with high flows over short distances, but considerable longer distance flows (mostly used for heterogeneous agglomerations such as manufactured and end-use agriculture commodities).

Examples of the slope of these distance decay functions are depicted in Fig. 4.4, depicting the exponential and power function for three different decay parameters. It is important to note that the exponential functions decay toward zero, whereas power functions hold over distance and will never actually reach zero. Exponential functions also drop at a must faster rate than power functions. The solid black line (power −0.01) is, for example,

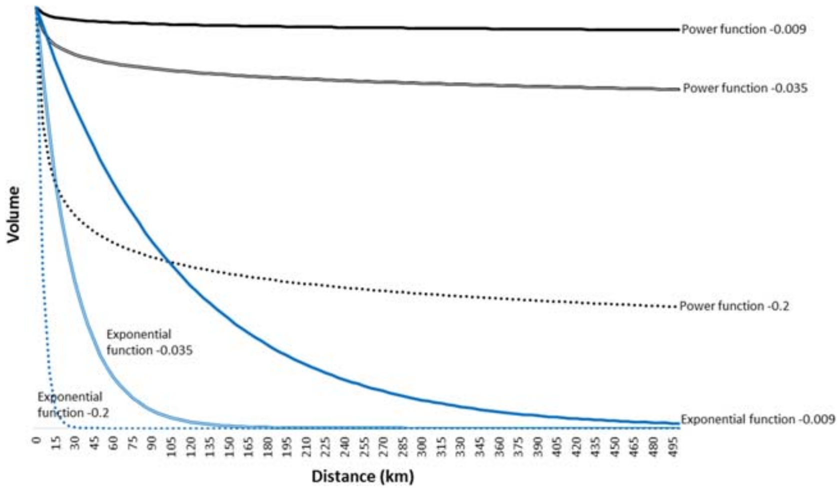


**FIGURE 4.4** Examples of different decay factors for a negative power function and negative exponential function.

more suitable to a commodity-like motor vehicles where distance does not play a role and freight will travel far distances to meet all demand and buyer preferences. The blue dotted line (exponential −0.2) is more suitable to a commodity where distance is extremely important such as where the value is extremely low (e.g., stone) or even where it is a generic product and can be replaced by many other products. All products have their own unique demand behaviors because of many different reasons, such as brand, price, diversity, generic, or specialized products and concentration of supply. Flowing from this, each commodity has its own freight footprint, and for each footprint, the closest matching decay function and parameter should be used.

The above parameters are operationalized in a gravity model, as per Eqs. (4.3), (4.4) and (4.5) (De Jong and Van der Vaart, 2010).

$$Tij = Ai.Bj.Oi.Dj\mathrm{f}(Cij,\beta) \tag{4.3}$$

$$Ai = 1/(\Sigma j.Bj.Dj.\mathrm{f}(Cij,\beta)) \tag{4.4}$$

$$Bj = 1/\left(\sum i.Ai.Oi.\mathrm{f}(Cij,\beta)\right) \tag{4.5}$$

where Tij = the estimated volume of freight flows between origin i and destination j; Ai = the balancing factor for origin i that ensures compliance to Oi; Bj = the balancing factor for destination j that ensures compliance to Dj; Oi = the constraint value for origin i (i.e., total supply); and Dj = the constraint value for destination j (i.e., total demand). f is the decay function, where f(Cij,ß) = exp(−ß.Cij) in case of an exponential function and

$f(Cij,ß) = Cij^{-ß}$ in case of a power function, where $Cij$ = the distance between origin i and destination j (the resistance measure) and $ß$ = the decay parameter.

The availability of supply and demand data enables the use of a doubly constrained gravity model (De Jong and Van der Vaart, 2010) where total flows from a district equal the total supply from that district, and flows to a district equal the total demand at that district.

Equations (4.4) and (4.5) hold for a doubly constrained gravity model, if the constraint Eqs. (4.6) and (4.7) below are satisfied (through an iterative procedure):

$$\sum_j Tij = Oi \tag{4.6}$$

$$\sum_j Tij = DJ \tag{4.7}$$

In such a doubly constrained spatial interaction model where both the origins and destinations are known but the derived freight flows over the transport network are unknown, the problem is essentially confined to the estimation of a suitable decay parameter.

A road distance matrix is created to determine the flow data for the nonrail component of freight. A detailed national road network is constructed, allowing road travel times to be estimated between the various origins and destinations, penalized for the type of road. A lower resistance is given to national roads, so freight collates toward these highways, the logic being assumed improved travel time on highways. This refers to Cij in Eqs. 4.3 to 4.5, which typically refers to distance but can be adjusted based on estimated travel time or costs. It is adjusted by ranking roads through reducing the travel distance for highways and increasing the travel distance for rural roads.

At the outset of the South African gravity-modeling exercise, hypothesized distance decay parameters, informed by theoretical knowledge, were tested and compared with known flows. The "best-fitting" distance decay parameters were subsequently selected. These decay parameters have been fine-tuned over a period of more than 10 years. Annual application and interaction with industry have proven the accuracy of these decay parameters to model commodity-flow behavior. These decay parameters are used as a starting point for India, informed by known rail and port flows, and fine-tuned through iterative application of the gravity model. Many distribution patterns of commodities are substantially different between the countries, and no decay parameter can simply be applied to another county. One clear example of this is for sugar cane, whereby in South Africa, sugar cane travels very short distances of approximately 20 km from a plantation to a sugar cane mill. Sugar cane has a very low value and low natural demand in South

Africa, so it does not travel long distances across the country. In India, however, sugar cane travels much longer distances, and despite having concentrated production areas, it is sold on almost every street corner in dense cities, resulting in a demand for raw sugar cane all over the country. The decay parameter for sugar cane in South Africa is, therefore, completely different from that of sugar cane in India. A distance decay parameter is developed for each commodity group individually to account for the varying nature and utility of the commodity.

The gravity modeling is processed using software called FlowMap, which was developed at Utrecht University in 1990. The spatial planning software has been applied successfully in South Africa for various spatial planning purposes since 2000. FlowMap expands typical Geographical Information System (GIS) functionality to allow for the management and analysis of data that depict spatial relations such as distances, flows, travel times, and travel costs (Utrecht University, 2013). FlowMap uses the supply and demand tables, distance tables, and the decay parameters as input to generate flows from supply to demand points, which match the given decay parameter. If the decay parameter is unknown, FlowMap has the functionality to use an iterative procedure to derive the parameter based on the mean trip length of actual observed flows.

The convergence criterion must also be set. This determines how well the number of trips that is to be estimated from the origins and to the destinations has to equal the set variables for the origin and destination constraints, respectively. The convergence criterion also determines how well the mean trip length that is to be estimated has to equal the distance, as was set above (De Jong and Van der Vaart, 2010).

## 7. Model outline and key outputs of disaggregated national freight demand models

The model outline for India's FDM and South Africa's FDM™ is detailed in Table 4.2, providing insight into the depth of disaggregation.

With regards to the typologies mentioned in Table 4.2, general freight is classified into three typologies: (1) freight that flows on long-distance corridors (i.e., between major metropolitan areas such as Gauteng-Durban and Gauteng-Cape Town in South Africa); (2) freight that flows within metropolitan areas; and (3) freight that flows to, from, and within rural areas. Corridor flows typically constitute higher value manufactured goods converging over long distances, with a multitude of endpoint O-Ds; metropolitan flows are the diverse distribution flows in often congested cities; and rural flows have many medium and short distance flows, mostly serving the agricultural market. (For freight flows within metropolitan areas, also refer to the limitations discussed at the end of the chapter.)

The key outputs of disaggregated national FDMs are sectorally disaggregated domestic, import and export freight flows in tons, ton-kilometers, and

**TABLE 4.2 Model outline of the disaggregated national FDMs.**

| India's FDM | South Africa's FDM™ |
|---|---|
| • Disaggregated freight-flow components:<br>  ◦ 672 geographical areas, that is, 451,584 possible O-D pairs;<br>  ◦ 31 commodity groups grouped into eight cargo types;<br>  ◦ Three inland modes (road, rail, and inland water) and specialized pipelines<br>• Aggregate classifiers:<br>  ◦ Typology: corridor, metropolitan and rural freight;<br>  ◦ Modal shift potential: Intermodal friendly, waterway friendly, or status quo<br>• Transport costs:<br>  ◦ Adding actual railway and waterway transport costs to relevant O-Ds (as received from operators)<br>  ◦ Estimating costs for nine road cost drivers on O-D level to enable cost–benefit analysis.<br>• The result of this process is a database of about 4 million unique records | • Disaggregated freight-flow components:<br>  ◦ 369 geographical areas, that is, 136,161 possible O-D pairs;<br>  ◦ 83 commodities grouped into nine cargo types;<br>  ◦ two inland modes (road and rail) as well as specialized pipelines and conveyor belts<br>  ◦ A 30-year forecast at 5-year intervals for three scenarios<br>• Aggregate classifiers:<br>  ◦ Typology: corridor, metropolitan and rural freight;<br>  ◦ Modal shift potential: Intermodal friendly or status quo<br>• Logistics costs:<br>  ◦ Adding actual railway transport costs to relevant O-Ds (as received from operator);<br>  ◦ Estimating logistics costs per component on O-D level (transport, storage costs, inventory carrying costs, and management and administration costs).<br>• The result of this process is a database of about 1.2 million unique records |

FDM, freight demand model; *O-D*, origin-destination.

TEUs for containers, between the geographically disaggregated supply (origin) and demand (destination) areas.

## 8. Freight flow segmentation

To classify freight for the purposes of policy development, investment prioritization, and modal optimization, freight flow segments are defined. The assimilation of freight flows is independent of the modeling process and derived from the economy's basic value chain and its related logistics requirements, as illustrated in Fig. 4.5.

Freight flows take place from the place of extraction or manufacture to the place of utilization or consumption, resulting in key flow patterns, as indicated in Fig. 4.6. This basic value chain holds true in any economy (specific exceptions, e.g., if no bulk minerals are exported just means that that segment is not applicable to that economy, but it does not change the basic

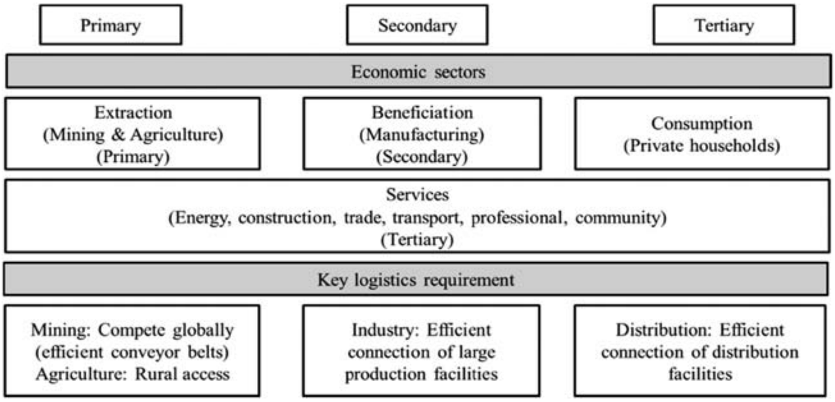


**FIGURE 4.5** Basic economic value chain and resultant logistics requirements (Havenga, 2012).

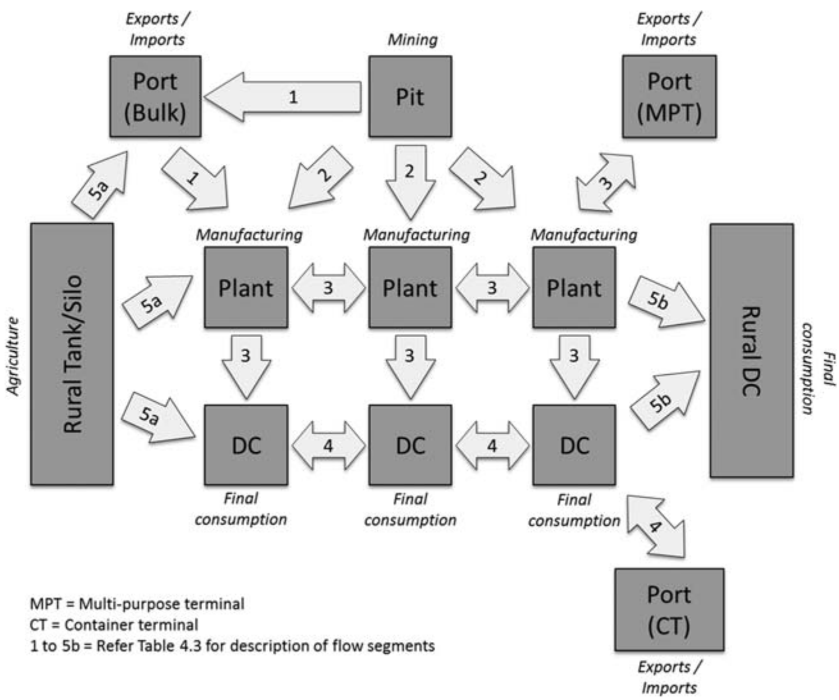


**FIGURE 4.6** Freight flow patterns derived from the basic economic value chain (Havenga, 2012).

value chain) and serves to classify the disaggregated commodities into logistically sensible segments to provide information about freight flow origins, destinations, and flow densities for investment purposes (road, rail, ports, intermodal hubs, or broader than just logistics to inform freight villages where manufacturing hubs can be included, and spatial planning to support agricultural renewal or optimal location of manufacturing facilities).

Five overarching freight flow segments can be identified, described in terms of the nature of the commodity and service requirement in Table 4.3. The size and resulting priority of each segment will be determined by the freight flow outputs of the disaggregated national FDM.

**TABLE 4.3 Description of overarching freight flow segments (based on a study by Havenga, 2012; numbering in the first column aligns with Fig. 4.6).**

| Freight flow segment | Nature of commodity and service requirement |
|---|---|
| 1. Export mining flows (pit-to-port) | Bulk export mining; rail-only transport with high density, long distances, limited origins with destinations the export ports. |
| 2. Domestic mining (pit-to-plant) | Bulk mineral mining for domestic beneficiation, stockpile to manufacturing plant, more complex flows with medium to long transport distances |
| 3. Intermediate manufacturing (plant-to-plant/DC) | Heavy break bulk requiring specialized wagons, plant-to-plant or plant-to-DC, high density, multiple origins with few destinations (typically DCs), long national transport distances but can also be short distances in metros |
| 4. Finished palletized goods (DC-to-DC) | Finished goods, palletized, complex SCM requirements but few origin–destination pairs (between DCs), high density, long national transport distances, and short distances within metros |
| 5. Rural extraction and delivery | 5a. Agricultural extraction—to cities or production centers, low density, many origin–destination pairs, and short to medium transport distances |
| | 5b. Agricultural manufacturing delivery—from cities/production centers to farms and rural areas, low density, many origin–destination pairs, and short-to-medium transport distances |
| | Rural interchanges—between farming areas, low density, and seasonal |

DC, distribution center; SCM, supply chain management.

## 9. Concluding remarks

This chapter reported on the development of disaggregated national FDMs for emerging economies where CFSs are not conducted. The building blocks of such a model were defined, namely, hybrid input data sourcing, development of spatially and sectorally disaggregated supply and demand tables, and the modeling of freight distribution via a gravity model. The benefits of this type of modeling are that it is comprehensive enough to provide quantitative analyses of an entire industry, commodity group, mode, state or country as a whole, yet it is sufficiently disaggregated for targeted analyses on specific regions, corridors, and commodities to inform policies and investments within the context of the national freight flow landscape.

Emerging economies are under the dual pressures of improving export market competitiveness while delivering on the urgent needs of economic development, spatial organization, and economic upliftment in the domestic economy (De Dios Ortúzar and Willumsen, 2011). Understanding the national freight flow landscape can facilitate the realization of these goals through informing policy development regarding modal shift, partnerships with the private sector, and spatial planning; identifying infrastructure investment priorities in fiscal-scarce environments; assisting in modal optimization to reduce freight logistics costs; and identifying key development nodes and logistics hubs. These applications within the context of the outputs of the FDMs for South Africa and India will be showcased in chapter 8.

The major challenges and limitations of disaggregated national FDMs are discussed below.

## 10. Challenges and limitations

The major challenges of the disaggregated national FDM approach discussed in this chapter are as follows:

- Cooperation from data custodians: The data intensity requires buy-in from a cross-section of data custodians. Although a wealth of data typically exists in most economies, obtaining these data can be onerous, mostly because of a silo-orientation (both in government and industry) and, in the case of large industries, confidentiality concerns.
- Data formatting: The format of disaggregated data is often very “raw” and requires significant data cleanup and classification across many thousands of data entries to enable, in some instances, its utilization as inputs to the spatial and commodity-level detail in the supply and demand tables, and, in other instances, as verification of existing data in the supply and demand tables.
- Continuity and skills transfer: The process is reliant on skilled modelers who have the ability to interrogate disparate datasets and, through a process of liaison with data owners, fact-finding, trouble-shooting, and

sense-checking, develop an accepted, valid reflection of national freight activity. Although the goal is always to enable in-country application of the model, the acceptance of data-driven macrologistics policy development and infrastructure planning is still gaining acceptance, hampering the allocation of (1) sufficient resources to update and apply these tools and (2) to motivate and empower current data custodians to value their contribution to a data-driven policy cycle by automating accurate data capturing and classification at source.

However, despite these challenges, this methodology has been applied in South Africa, sub-Saharan Africa, India, Vietnam, Mongolia, and Uzbekistan over the past decade. In addition, a provincial extension was developed in South Africa and a city extension in India. In all cases, the methodology proved sound, the population of supply and demand tables was possible, and the outputs added significant value to country-level understanding of the national, regional, and industry-level freight flow landscape. In a number of instances, this informed policy and infrastructure investments, as will be discussed in chapter 8.

This body of work can, therefore, serve as a use case to support motivation for data-driven policy development and infrastructure, which is dependent *inter alia* on a "pull" requirement from national governments (Beguy, 2016).

The major limitations of the disaggregated national FDM approach discussed in this chapter are as follows:

- It is not possible to distinguish short-distance movements (i.e., intradistrict and intrametropolitan movements) with the current methodology, as gravity modeling is not suited for microlevel modeling. It is, therefore, not possible to distill detailed vehicle routing from the current methodology, as via points and freight deconsolidation/consolidation centers cannot be added. A possible solution would be to combine agent-based modeling with gravity modeling. The gravity model will then be set up to distribute freight to DCs (or via points), whereas the truck trips generated through agent-based modeling (via, e.g., global positioning system data) can be enhanced with a commodity view obtained from the gravity model. The integration of these two approaches is being investigated.
- There is a concern that decay factors could be negatively impacted by the removal of known flows, as it impacts the "pull" of data points. The rationale for removing known flows is that it reduces the modeled component, and the current software cannot calibrate to known flows to ensure the accuracy of final outputs (known and unknown flows). An extension to the gravity modeling software is being considered to allow for the latter.
- Data disaggregation to detailed spatial and commodity level for final consumption of manufactured goods is the most challenging and is typically

developed via proxy because of the detailed sectoral and commodity disaggregation required.

- For context, in the primary sector data, disaggregation is relatively straightforward. Government and industry bodies collect and report data of supply points, whereas import and export data groupings correlate well with supply data, serving as validation points and, in the case of exports, inform demand. Large intermediate demand points are easy to identify. In the secondary sector, large production points (which are intermediate demand points for the primary sector, as well as supply points for further manufacturing or for distribution to DCs to serve final demand) are relatively easy to identify in an economy, through established data and discussions with industry bodies, supplemented with desktop research where required.
- Contrary to typical criticism, higher levels of disaggregation (commodity and spatial) can, however, actually reduce risk factors, as it is easier to verify data on a Pareto basis, and it facilitates engagement, as specific data points can be isolated, discussed, and updated if required.

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Chapter 5

# Destination matrix building and disaggregated choice modeling using tax revenue data

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## Highlights

- Lack of data, limed knowledge, experience, and funding for data collection and data handling.
- Development of hybrid approaches that combine from different public authorities.
- Successful application of the approach for the development of origin–destination matrixes and mode choice models.

## 1. Introduction

Data availability in the freight sector has been pointed out as one of the major causes for the slower development of the modeling techniques, compared with passenger transport (Tavasszy and de Jong, 2013). The quality and availability of data are important factors that affect not only the level of detail of the model but also the type of models that can be used (Chow et al., 2010). For example, if only aggregated data on market shares without any information on individual choices are available, a modal choice model will have a limitation on its predictive and interpretative value.

Data in freight are generated by the commercial relationships between firms. The records generated by these transactions hold sensitive information to their core functioning. This results in the reluctance to share data because of the risk of losing competitive advantage.

Data asymmetry could be responsible for the difference in the models of developed and developing countries. In the former, there are more

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consistent, compatible, and comparable data sources, such as EUROSTAT, and more specific projects and data collection, such as the Commodity Flow Survey for the United States. Nevertheless, data sources are far from perfect, as they are not always periodically updated and are not always intended for transport modeling. For example, the French flow survey (ECHO) of 2004–2005 is still used for new models and applications (e.g., Jensen et al., 2019).

In emerging countries, although it is difficult to generalize, data are harder to collect. Sources tend to be less reliable, with shorter and not always consistent time series. In some cases, contradictory data can be found even if they all come from governmental sources. This is aggravated by the lack of clarity in the method used for collection.

Another issue found at this level is the lack of compatibility among different databases. As statistical records of different organizations were created and developed independently, they have different nomenclature and levels of detail that make data compatibility a much more difficult job.

Although the unstructured data are a big problem, it can bring some opportunities. Not having structured methodologies to construct and update data can give the chance to innovate in data collection and processing by generating new and more suitable models for the needs of developing countries.

These opportunities have not only appeared for freight transport. In passenger transport, big data and ubiquitous data have good prospects and several challenges. Ubiquitous data, generated independently and asynchronous from many different sources (Hotho et al., 2010), need further treatment to fill the gaps derived from the passiveness of its generation. This process, also known as data augmentation, is crucial to make the data usable for modeling.

Data augmentation is the process of obtaining new data to compliment an existing data source. This can be made by exploiting the current database or by relying on other sources to compliment it. For this stage, it is important to know the type of model to be used to gather the appropriate data. For instance, if the objective is to investigate traffic allocation, network and origin–destination (OD) data are needed; and if the objective is to build disaggregate behavioral models, data about the original choice situation have to be collected.

For example, detailed warehouse location data for developing a freight transport management assessment for the rice industry in Vietnam have been used (Binh, 2017). This level of detail is difficult to find, especially where data exhibition and collection are more standardized, the case for developed countries. Other data sources with high potential come from tax agencies. Databases from these sources are stable and structured because of their role to discover and control tax fraud schemes.

The need to maintain the tax secrecy poses the greatest challenge for their application in transport modeling. Normally, the privacy issue is the reason why these data are not available. Nevertheless, with the proper measures to protect privacy, it can be shared from the government for modeling and policymaking proposals. This is the case of the electronic invoice (EI) in the state of Rio Grande do Sul, Brazil, and the consignment bills (CBs) for grain transport in Argentina.

In the context of the Transport and Logistics State Plan (PELT, for the abbreviation in Portuguese) of Rio Grande do Sul, information about the movement of products measured in monetary value was available. This information was used to build OD matrices to identify the greatest infrastructure bottlenecks.

The CB used in Argentina consists of the origin and destination of all grain products and was made to have a tighter control on agricultural goods movements. It is a unique dataset to help understand the behavior of one of the most important productive sectors of the country.

The objective of this chapter is to describe and discuss the use of tax agency data for the cases of Brazil and Argentina. The data available, the processing, results, and augmentation will be addressed in both cases. Finally, some considerations on how to set up collaboration strategies with tax agencies to obtain the data. The chapter continues with section 5.2 discussing in depth the case of Brazilian EI use for OD matrices, whereas section 5.3 will discuss the use of CB for OD matrices and behavioral modeling. Finally, section 5.4 will show the conclusions of the chapter.

## 2. Description of the data sources

### 2.1 Electronic invoices

Brazil is the biggest country in Latin America in terms of population, gross domestic product (GDP), and size. Because of the federal nature of the country, several responsibilities fall on each state's government. One of these is transport infrastructure development and planning. In this section, the PELT of Rio Grande do Sul is addressed. In particular, the development of OD matrices from taxation data and its further validation is described.

Rio Grande do Sul is the southernmost state in Brazil. It borders with Argentina to the West, Uruguay to the South, and the Brazilian state of Santa Catarina to the North. The economic structure is diverse, ranging from agricultural production (for internal consumption and export) to the industrialization of heavy machinery.

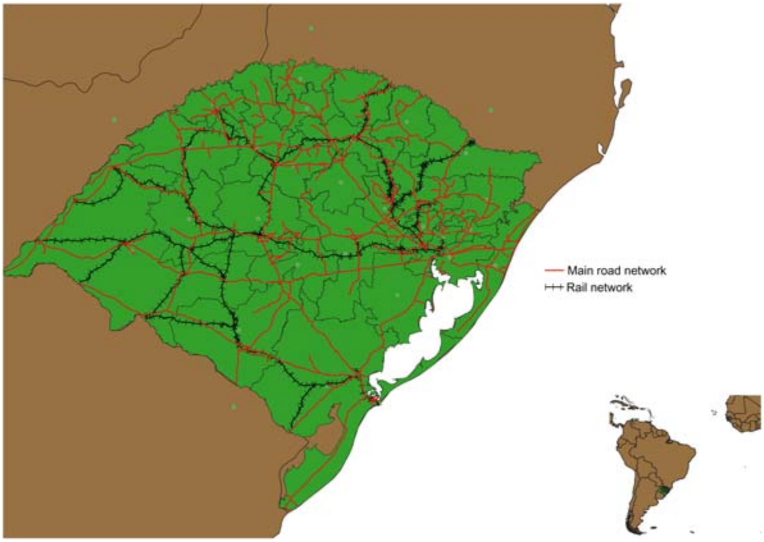


**FIGURE 5.1** Main roads, railways, and waterways in Rio Grande do Sul.

The products are moved mainly by road, with 85% of the market share. Of the entire road network, only 8% is paved; almost all the roads under federal administration are paved; about 60% of the roads under state administration are paved; and about 98% of local (municipality level) roads are unpaved. The railway networks and the waterways are mostly oriented toward the export of unprocessed commodities to the port of Rio Grande, the only exporting port of the region. Fig. 5.1 shows the available transport network in the state.

The PELT had the objective of generating long-term infrastructure policy in concordance to national-level logistic plans. By establishing the baseline flows and forecasting them under various scenarios, infrastructure constrains were identified.

## 2.2 Description of the instrument

The tax collection instrument used by the PELT was the EI, created in 2005. Over the years that followed the introduction, the adoption of the EI for different segments of products and sectors was made mandatory. By the year 2010, most of the goods and services of the economy had to adopt the EI. By 2014, the year of the data collection of the PELT, its use was widespread, and the databases consolidated.

The EI had the objective of replacing paper invoices that documented the movements of goods or the provision of services. The result was a simplified way of communication between companies and the taxation authority.

Data contained in the EI varied from product to product, but some information was common to all. These were data about the provider and client (location, name, and ID), the product (ID, quantity, and value), and taxes paid in the transaction.

### 2.3 Processing

To guarantee fiscal privacy, the data provided by the taxation agency of the state of Rio Grande do Sul [State Department of Taxation and Finance (SEFAZ), abbreviation in Portuguese] did not show the businesses involved, protecting taxpayers' confidentiality. Data were then aggregated at a macro zoning level. The 28 traffic zones adopted are consistent with the ones used by the Secretary of Planning, enhancing the interoperability of the information and results.

For origins or destinations outside Rio Grande do Sul, five extra zones were added. Two for Brazilian locations (Brazil East and Brazil West), one for eastern international flows that go through Argentina, one for southern international flows that go to Uruguay, and one for the flows that goes to the port of Rio Grande. In the latter, international export flows were confounded with coastal shipping to the rest of Brazil.

Another aggregation that was made by PELT had to do with the products involved. The EI has detailed information regarding the description of the product, something that is not necessarily needed in a long-term plan. Twenty-eight different product types plus one for general cargo were extracted. Only 5% of the movements, measured in Brazilian Reais, were discarded due to lack of consistency.

## 3. Consignment bills

Grain production is one of the most important economic activities in Argentina not only because of its participation in the GDP (10%), exports (70%), and tax revenue (10%) but because of the other economic activities related to the supply chain involved, such as crushing and agricultural machinery.

The grain supply chain can be divided into two, as shown in Fig. 5.2. On one side, there are the receivers, such as exporters, industry, or consumers. On the other side, there are the senders, such as producers and consolidators. Producers have two options for selling their crops. They can sell their products to exporters or industry (directly for the large producers, although brokers for the other producers) or to a consolidator. Because 46% of the production is carried by a large number of producers (Regunaga, 2009), they are likely to use the latter option. Besides, some large producers might also need conditioning for their seeds before selling

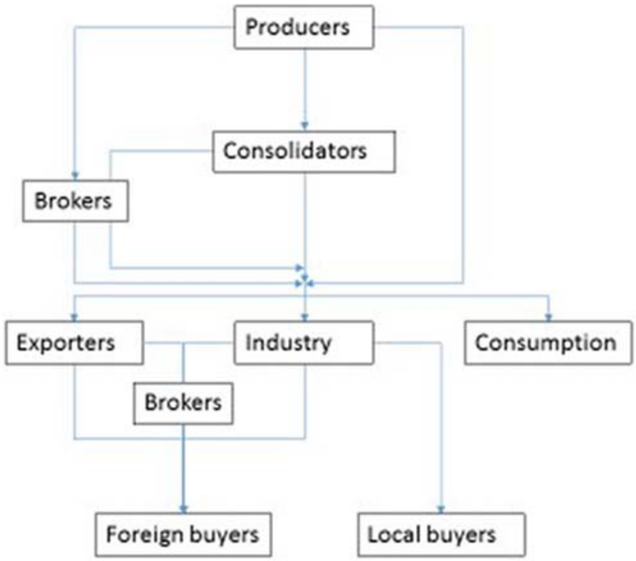


**FIGURE 5.2** Grain supply chain. *Adapted from Instituto Nacional de Tecnología Agropecuaria (2009).*

them, and this is normally carried out by consolidators. Consequently, consolidators are a key agent in deciding where and how the inland transport is made in Argentina.

The mode choice of the grain is heavily unbalanced toward road. Around 84% of the volume is carried by truck, 14% by rail, and the rest by barge (Regunaga, 2009). Transportation represents an important share of the overall production costs. As a major factor in the competitiveness of the main exporting sector of the country, there is continuous interest in lowering logistic costs and increasing its efficiency.

Gaining a more in-depth knowledge of the transportation systems (and decisions) and the location of the production and demand centers is crucial to properly address this issue. Insights gained by OD matrices and behavioral models have an important role in this understanding.

## 3.1 Description of instrument

The CB for agricultural products originated as a way for the tax agency to control the commercialization of grain in Argentina. It works as proof of transfer of the grains. When it was first established, each of the participants of the transport (sender, receiver, and transporters) had a paper copy as a proof of the transaction. In 2009 the electronic support was implemented.

The CB had information on the sender (name and location), the transporter (name, mode, and tariff), the receiver (name and location), and the

**TABLE 5.1 Data available from the CB.**

| Field | Data type | Description |
|---|---|---|
| ID | Integer | Line ID |
| Transport | Categorical | Mode of transport |
| ID of CB | Integer | CB ID number |
| Harvest year | Categorical | Year the grain was collected |
| Grain specie | Categorical | Type of grain transported |
| Origin ID | Integer | ID of the origin |
| Origin | String | Full name of origin |
| Destination ID | Integer | ID of destination |
| Destination | String | Full name of destination |
| Weight | Integer | Volume transported in kg |
| Unloading date | Date | Date of unloading |

*CB*, Consignment bills.

product (type, weight, date of loading, and unloading). To protect the fiscal privacy of the organizations involved, some data were not shared. This consisted of information about the firms involved, prices, and date of unloading. Table 5.1 shows the structure of the shared data.

As the data recorded in the CB are about grain movement, each line represents an individual shipment. This means that if a sender has to break a bigger shipment into smaller ones to comply with the capacity constraints of a mode, this would mean that multiple records will appear in the database.

## 4. Origin destination matrix

OD matrices are that describe the movement of goods (or people in the case of passenger transport) between two zones. OD matrices allow transport modelers and planners to identify the main flows of goods between two pairs. The main differences between freight and passenger OD matrices are that freight flows do not always go through the shortest route between origin and destinations because of the need for the difference between inventory flows and production–consumption flows (Friedrich et al., 2014).

OD matrices are mostly used as an input for allocation models that can estimate the volume of flows through the networks. This use of the matrices is the objective of both applications in this chapter. The first one uses the EI to mount and calibrate the OD matrix for Rio Grande do Sul, Brazil, and the second one shows the data augmentation process for building the matrices for grain transport in Argentina by using CB. This section is based on the reports of the works (Plano Estadual de Logistica e Transportes, 2015a,b; Ministerio de Transporte de la Nacion Argentina, 2017) and interviews with the coordinators of the projects (for the PELT that uses EI, the coordinator was Professor Luiz Afonso dos Santos Senna from the Universidade Federal do Rio Grande do Sul, and for the CB, the coordinator was Lic. Mariana Melgarejo, from the Ministry of Transport of Argentina), as the author of this chapter did not participate in their elaboration.

## 4.1 OD matrices for EI

The biggest challenge for using the EI for an OD matrix was to obtain the volume of the flows. Although in the data there was a column that referred to volume, it was not uniform across the entire database. Measurements such as units, boxes, or tons appeared in the data, among others. Even when tonnage was used, the reliability of the measure was considered to be relatively low because it was simply a declaration of quantity and was not necessarily the actual amount transported. To infer the quantities, some measure of the unitary value per ton had to be obtained.

Depending on the level of homogeneity of the group, different sources were available. For exported commodities that are typically homogeneous, a database for international trade was used (Ministério da Indústria, Comercio Exterior e Serviços, 2014). These records are a very reliable source of information of weights and monetary value because both amounts are recorded by the government and not declared by the exporter. This makes it a preferred source and used when available. The main issue was that the results obtained from international trade records might not represent the heterogeneity and relative participation of different products in the groups.

The second source used was the EI data itself. Because it relied on declared weight values, there was high variability on the amounts. Nevertheless, it contained enough disaggregation to absorb the heterogeneity present in each product category. A preliminary OD matrix with monetary values and another for weights was made to estimate the unitary value. After dividing both matrices, outliers were excluded before averaging them by product group.

Two commodity types were treated individually. The first one was vehicles and auto parts, where volume data from the EI were used directly. It was considered that because of the high value of the product, the measurements of volume found in the database were accurate enough. The second one was fertilizers, the main imported product in Rio Grande do Sul (in tons), where the average value and tonnage per truck were used.

Once the unitary value of all product types was obtained, the final OD matrices were estimated at a macro zone level. Traffic allocation at a macro level has a lot of problems regarding the aggregation of origins and destinations because all flows concentrate on those points. This causes traffic to get assigned heavily into few routes, losing realism.

Additional data sources were used for further validation of the matrices and projected flows. OD surveys and traffic counting were used to disaggregate further the data from the EI. With 19,000 surveys distributed in 60 points of the motorways, factors that proportionally distribute intra- and extra-traffic zone flows were calibrated and applied (Plano Estadual de Logistica e Transportes, 2015a). Eqs. (5.1) and (5.2) show the estimation of the factors of attraction and production.

$$Fa_{iz} = \frac{v_{ai}}{\sum_z v_{az}} \tag{5.1}$$

$$Fp_{iz} = \frac{v_{pi}}{\sum_m v_{pm}} \tag{5.2}$$

where $Fa_{iz}$ is the attraction of subzone i that belongs to the macro zone z, $Fp_{iz}$ is the factor of production of subzone i belonging to macro zone m, and $v_{ai}/v_{pi}$ are the volumes registered with destination/origin in subzone i. Eq. 5.3 shows the final decomposition of the volume between macro zone z toward macro zone m $\left(V0_m^z\right)$ into the volume from micro zone i to j $\left(V1_i^j\right)$.

$$V1_i^j = V0_m^z * Fa_j{}^* Fp_i \tag{5.3}$$

Each set of factors was estimated at a macro zone level, so the interpretation of them is how strong a district attract/generate cargo. An alternative to model this was to calibrate a gravity model to take into account transport impedances. The model proposed is a simpler one that only recognizes the relative importance of a district rather than the nature of the transport. With this method, the original OD matrices of $33 \times 33$ were decomposed into a matrix of around $500 \times 500$.

Additional traffic counting was made in 289 sections of the roadway for a week each. From these values, an approximate of the volume transported in those months was estimated. With the information of the toll posts, the seasonality effect was taken into account to annualize the volumes. Finally, the OD matrices were corrected by modifying the original OD matrix to fit the traffic counts. The method consists of minimizing the residuals between projected traffic and the traffic counts. Proportional adjustments are made to the seed OD matrix in an iterative way until a convergence rule is satisfied (Nielsen, 1998). In Fig. 5.3, the traffic allocation is shown for the production of soy.

This last validation procedure was made only for the baseline year. For the following years, the SEFAZ provided the same database of EI aggregated at a district level. This provided the information necessary for the allocation without having to rely on traffic counting and surveys.

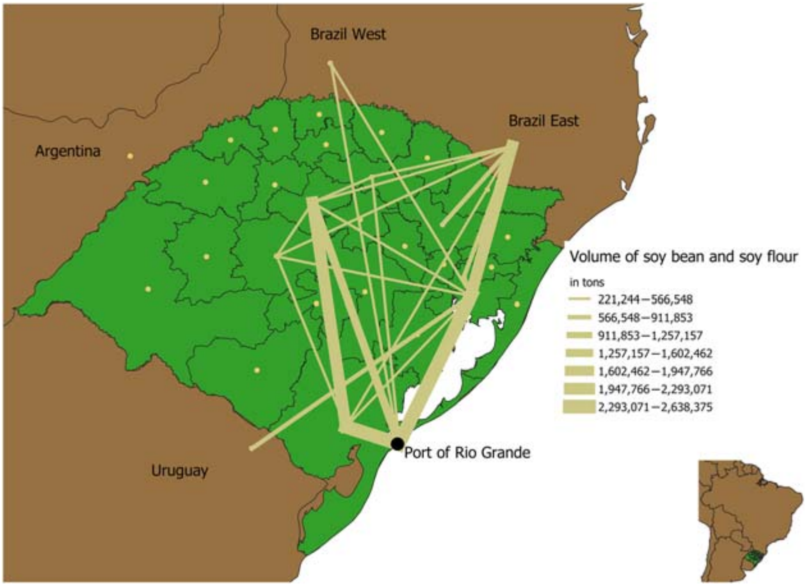


**FIGURE 5.3** Origin and destination of soy.

OD matrices elaborations were the first step in building the models needed to identify infrastructure priorities. The expansion of the matrices was made following economic activity indicator's forecast, but the analysis of this model does not belong to the scope of the current chapter.

## 5. OD Matrices for CBs

The most straightforward application of the CB is to obtain OD matrices per product and mode. The results for all goods present in the CB and the main products in Argentina are published by the Ministry of Transport of Argentina (Ministerio de Transporte de la Nacion Argentina, 2017).

To obtain the product volumes, simple database processing such as grouping by OD pairs was made. For this particular application, the country was divided into 123 zones according to production profiles, population size, and other economic variables (Benassi, 2015). This zoning, although aggregated, gave the possibility to use other data sources and to compare results with previous works.

Some additional data cleaning was made to eliminate outliers. Several shipments with OD pairs without any commercial logic or very small shipments were excluded from the data.

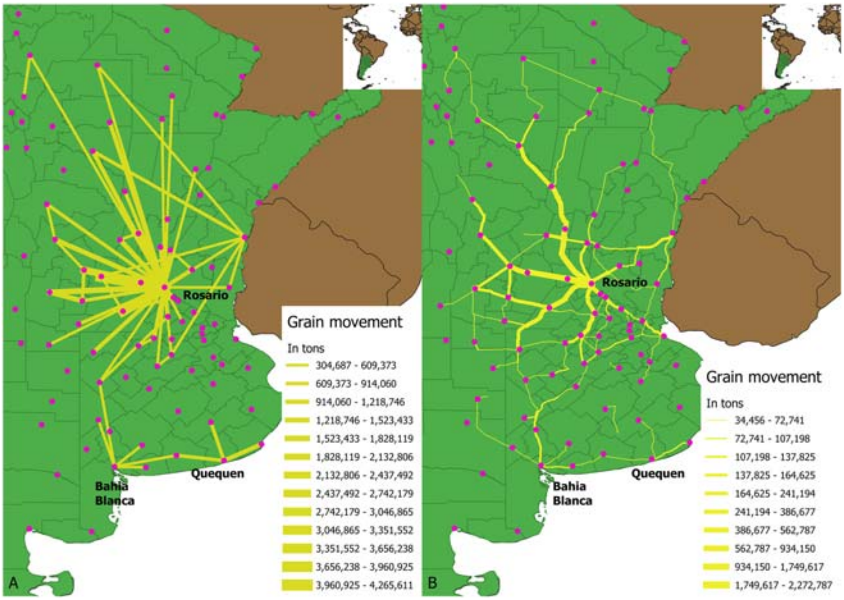


**FIGURE 5.4** (A) OD of grains in Argentina. (B) Allocation of grain movements to the road network.

## 5.1 Data augmentation

For this application, few external data sources were needed. The main external inputs were related to zoning and aggregation aspects.

Regarding the allocation of flows to the existing network (one of the main objectives of the study), data on the network were used. It consisted of geolocated data of the main roads and railways that connected the centroids of the 123 zones. As only the main links between the centroids were used, the minimum path algorithm was used. Because of the lack of supporting traffic counts, only the volumes at the port were validated. The results for grain movement are shown in Fig. 5.4.

# 6. Mode choice

For many years, freight demand modeling relied on aggregate models, mainly because of data scarcity. Disaggregated models consider each decision as an individual choice. Modes yielded at disaggregated levels are more compliant with microeconomic theory.

Random utility maximization (RUM) is the theoretical background of most disaggregate behavioral models (Domencich and MacFadden, 1975). It assumes that decision makers try to maximize their utility in every choice. The utility for mode $i$ for the choice maker $q$ is given as follows:

$$U_{iq} = V_{iq} + \varepsilon \tag{5.4}$$

where $V_{iq}$ is the observed utility, and $\varepsilon$ is an error term. It is in the $V_{iq}$ where the modeler characterizes each mode. The attributes could be cost, time, and reliability, among others. RUM establishes that the alternative with the highest utility is the chosen one.

Assumptions on the error term dictate the model form. If $\varepsilon$ follows a type I extreme value distribution, the probability $P(i)$ of an alternative $i$ being chosen among the choice set $j$ is given by the multinomial logit:

$$P(i) = \frac{e^{V_i}}{\sum_j e^{V_j}} \tag{5.5}$$

It can be seen from the equation which data are needed for modeling choices. Four categories of data are required. First of all, data on the choice made are required. The second group is the choice set the individual is faced with. In other words, which alternatives are available to be chosen. The third category is the attributes that characterize each alternative (such as time, cost, and reliability). Finally, information on the choice maker (or shipment) can also be used to enrich the model.

Additional model structures are also available that can give a better understanding of the choice and provide better models. Some examples are the nested logit, cross nested logit, ordered logit, and probit.

Difference among choice makers can provide useful insights into their behavior. Heterogeneity can be introduced with random components in a mixed logit or with observed heterogeneity, such as socioeconomic variable interaction or latent class modeling.

## 6.1 Electronic invoices

Modal choice was not modeled in the PELT with EI data because of the aggregated nature of the data. Modal choice was addressed through an stated preference survey to identify the preferences of freight logistics managers to encourage intermodality and reduce overall logistics costs (Larranaga et al., 2017). It is considered to use the EI data in the future for this application.

## 6.2 Consignment bills

This database of individual shipments had the potential to be used for modeling disaggregate modal choice. To use it, the original choice situation had to be recreated. Owing to the characteristics of the privacy concerns the data had, some of the parameters of the choice situation had to be inferred. The process of data preparation and processing used in Southeast Buenos Aires Province for behavioral modeling (Tapia et al., 2019) is described in this subsection.

## 6.3 Data processing

The main challenge was derived from the structure of the data and its original objective. The CB was created to track individual grain movements, so each record can actually be part of a larger choice. In the hypothetical case of a shipment of 300 ton of soy, if it were going to be transported by truck, because of capacity constraints, it would have to be divided into 10 trucks. As a consequence, 10 different CB would be issued, and thus 10 different records would appear in the data. Nevertheless, only one decision was made. Not taking into account this issue may lead to an overrepresentation of road share. This issue is less likely to appear in other modes because they can transport larger loads.

To amend and remake the choice situation, multiple shipments had to be merged. It has been done by assuming that consecutive records from the same location, product, destination, and date come from the same larger shipment. The main underlying assumption is that when the sender fills the electronic form, it orders more than one at the same time, so consecutive numbers are issued.

The assumption is broken if the sender decides to add an extra truck *a posteriori* or if somebody else fills a CB with the same characteristics immediately after. The former would underestimate shipment sizes because they would exclude shipments from the same decision. The latter, although much more unlikely to occur, would overestimate the size of the shipments because of the over inclusion of records. After this processing, the database went from 2,932,686 records to 1,104,243.

## 6.4 Data augmentation

The compacted database has information on which mode was chosen, the (estimated) size, date, origin, and destination. This has no data on the choice itself or the not chosen alternatives, so additional information was gathered to recreate the full choice situation.

The first step was to decide the choice to be modeled. It could be simply mode choice, destination choice, or a mixture of both. In this case, the joint choice of mode and port was modeled. Consequently, the choice set was going to be all the combinations between ports and modes. Fig. 5.5 shows the main export ports, the rail network, and the productive area of Argentina. The products to be included in the analysis were the main exported agricultural products because of its importance in Argentina's economy. These were soy, wheat, sunflower, and maize.

There are three main ports in Argentina: Rosario, Bahia Blanca, and Quequén. Rosario consists of multiple terminals located alongside the Paraná River. The multiple terminals cover over 46 km of river banks and other cities, such as San Martín and San Lorenzo. It moves approximately 68% of all

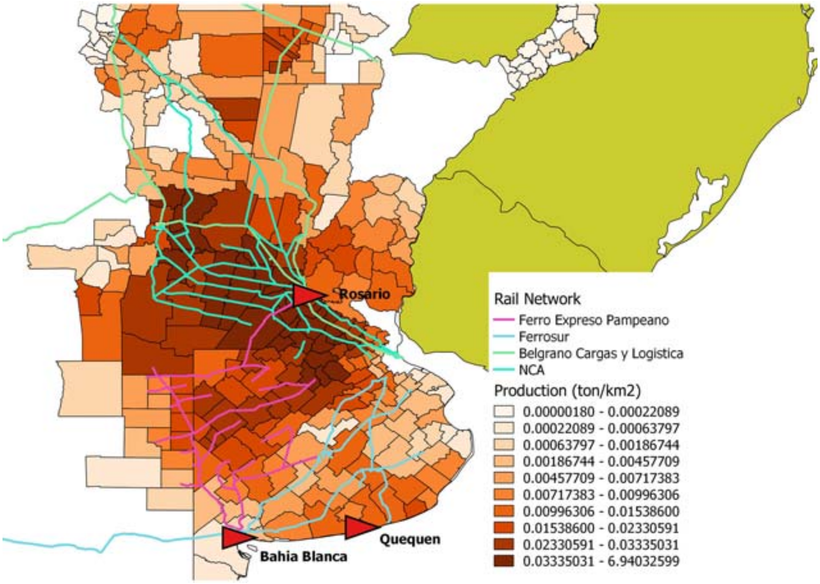


**FIGURE 5.5** Main agricultural productive area and ports of Argentina.

grain exports of the country, and its price is normally used as a reference for grain commercialization. Most crushers and grain-related industries are located in the surrounding area.

By grain volume trade, Bahia Blanca is next in size. Located in south Buenos Aires Province, it is the deepest port of Argentina and goes directly to the Atlantic Ocean. For some trade routes, ships that are loaded in Rosario come afterward to Bahia Blanca to be completed. There is also a strong crushing industry, alongside with petrochemical manufacturing.

Another grain port worth mentioning is Quequén, in the southeast Buenos Aires Province. It is a port located in a river mouth, making it dependable on river ties for having an operative draught. Multiple operational issues have caused the prices paid in this port be systematically lower than other ports. Smaller ports, such as Ramallo (located on northern Buenos Aires Province, close to the Parana River mouth), were identified, yet discarded for analysis because of its low share of shipments.

The element chosen to characterize port attractiveness was the price paid for the products at the port. In this context, the Free Alongside Ship price was chosen because of being a published price at each port, which is used as a reference for transactions. Each port publishes at the end of the day the average price each grain was negotiated. When a round (day) had no price, there were no sales at the port, so the reference used is of the last available. This means that with the incomplete series of prices, it is possible to fill the gaps. Prices of soy, wheat, sunflower, and maize for the year 2014 were included (FyO, 2018).

Transport network information was necessary to obtain basic information about the conditions of the transport. The objective was to process the network data to produce distances, times, and costs. Georeferenced maps for rail and road in the format of shapefile were provided by the Ministry of Transport. The road network consisted of a complete representation of the primary, secondary, and tertiary ways. The latter were discarded for the analysis because they were the small rural paths.

The rail network used had some problems with its integrity. After the privatization of the railway, several lines stopped functioning, which was ill informed to the regulatory agency. A big effort of the agency that controls rail infrastructure was made to obtain the operational status of more than 25,000 km of rail tracks. In the shapefile, data about condition of the track, maximum speed, and length were among the information available. Nevertheless, some problems were found when using data such as inconsistent speeds or some broken links. This resulted in using this information as a reference for average speeds for rail rather than using the actual reports of the network.

A python package called "networkx" was used to calculate the distances using the Dijkstra algorithm to find the shortest path. One path for road and two for rail (minimum distance and minimum time) were extracted, to capture network differences and travel times. All the combinations of origins and port destinations were considered.

Truck pricing is regulated in Argentina, so the prices per ton km are published (CATAC, 2014). Nevertheless, this is not perfect information because it has been reported that larger companies pay below this price and that some consolidators have their fleet.

Railroad prices are not regulated, and most companies do not publish them online. The only price table found was for the public-owned company and was used as a reference for the prices of all the network (Belgrano Cargas y Logísticas, 2014). Different pricing strategies appear during the year, and it has been mirrored in the augmented data.

Additional information on the region could be deduced from the data. From the distance matrix, for each origin, the closest port is noted. In regions that are within the influence, more than one port can be identified. From the Ministry of Agroindustry, some regional profiles of the consolidators (e.g., the number of companies or number and size of storage facilities) were used to further describe the firms in a region (Ministerio de Agroindustria, 2016). This information can be used to capture some heterogeneity in the choices made in the data.

Some data about the level of service the rail can deliver to a given area could be inferred from the CB. Knowing that the rail does not provide an everyday service, and considering that there is a constraint in rolling stock during high season, it can be said that the smallest day lapse between two rail shipments of the same region is the best headway the rail can provide to that area. To do so, a filtered data from train had to be sorted by location and then by date. After that, the minimum difference between two dates would be the value of the headway.

Considering that the date provided is the unloading date, it could happen that the same train is unloaded in different days. In that case, the processing would throw a very small and unrealistic value for the headway. To solve this, a minimum headway had to be established. The value adopted was of 5 days for this application and came from interviews with users of the system.

Another element that can improve the results in the choice models is to refine the availabilities for each choice. Allowing the possibility of an alternative that was actually not available in the choice set could lead to bias in the parameters estimated.

It could be inferred that if there was no record of any train service to a certain location, rail was not available in the choice set of that site. Something similar could be done with ports, although every port could theoretically be reached by truck. Further modeling could be made to refine this, as made for passenger transport (Calastri et al., 2017), but it escapes from the scope of the chapter.

Most of the data gathered to augment the CB data had information on characteristics of either the origin or the destination of the choice. The final step was to join the tables into a single one to recreate the choice task. Table 5.2 shows the data structure of the consolidated data.

By processing the CB and with the use of other sources, revealed preference (RP) data were generated that could be used to generate disaggregate modal choice models. Although it is very rich information, several assumptions had been made during data augmentation and processing. Therefore the definition of some variables could become less objective, bringing potential bias and problems in the estimation and interpretation of results.

## 6.5 Application

An example of the application is the modeling of the port and mode choice for grain consolidators. The case study is from a region between the two most important grain maritime ports: Bahia Blanca and Quequén, as seen in Fig. 5.5 (Rosario, is a fluvial port). This region is interesting for understanding the competition between both ports. The CB will provide RP data, meaning that the model would be suitable to estimate elasticities and to forecast future scenarios. The choice modeled was the mode (train or truck) and port choice (Bahia Blanca or Quequén).

To reduce the bias that could be introduced in the inference of the data augmentation, an SP experiment was done. SP has the advantage of being flexible and designed by the researcher, but it bases on hypothetical choices

**TABLE 5.2** Augmented data for disaggregated choice modeling.

| Field | Data category | Description | Source |
|---|---|---|---|
| FAS price | Attribute | One field per destination; price paid at destination | Stock market |
| Distance rail | Attribute | One field per destination; distance traveled measured in the rail network | Network |
| Distance truck | Attribute | One field per destination; distance traveled measured in the road network | Network |
| Freight cost rail | Attribute | One field per destination; time estimated through distance and cost per km | Rail company + network |
| Freight costtruck | Attribute | One field per destination; time estimated through distance and cost per km | Truck association + network |
| Headway | Attribute | One field per destination; minimum day separation between two shipments at the origin | CB |
| Time rail | Attribute | One field per destination; time estimated through distance and average speed | Network |
| Time truck | Attribute | One field per destination; Time estimated through distance and average speed | Network |
| Availability | Availability | One field per destination; dummy if destination is available for rail | CB |
| Choice | Choice | Mixed mode and choice used | CB |
| Grain species | Choice | Type of grain transported | CB |
| Shipment size | Choice | Volume of the shipment in kg | CB |
| Closest port | Choice maker | Hinterland the origin belongs to | Network |
| Installed storage capacity | Choice maker | Volume the origin can store in permanent facilities | Ministry of agriculture |
| Mixed hinterland | Choice maker | Dummy indicating if there are multiple port competing | Network |
| Date | Miscellaneous | Date of the unloading | CB |
| Dollar | Miscellaneous | Conversion rate ARS/US$ | Stock market |

*CB*, Consignment bill; *FAS*, Free Alongside Ship.

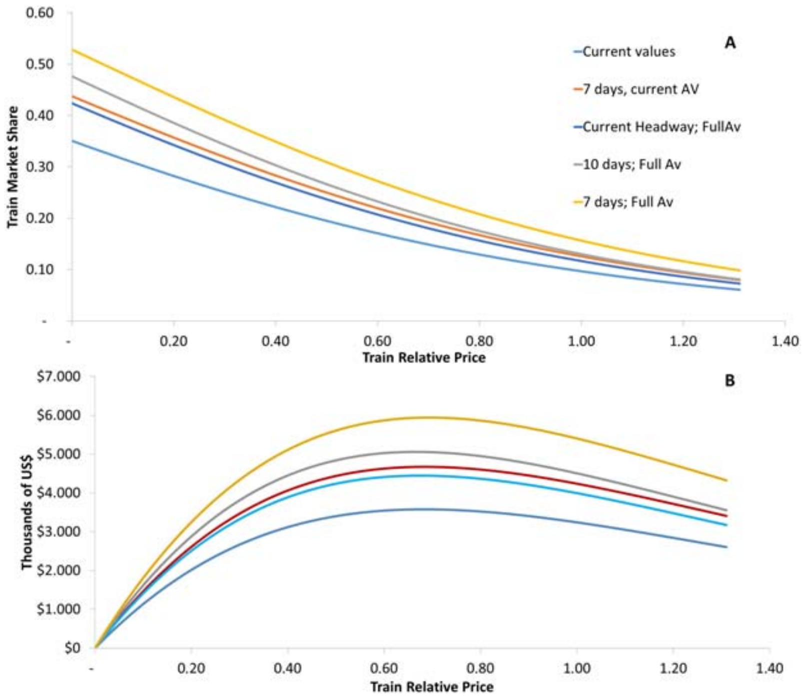


**FIGURE 5.6** (A) Simulated train market shares; (B) Simulated rail incomes.

that might not be reflected in real-life scenarios. The biggest strength of the SP experiments in this context is that the variables are correctly defined, whereas with the CB processing, they are estimations of the actual variables. This way the SP can potentially correct some problems derived with the high correlation between the explanatory variables. By modeling RP and SP data simultaneously, the weaknesses of each method are overcome (Hensher et al., 2008). This results in a model that could be used for forecasting and elasticity estimation while having better properties in the variable definition. The details of the SP and the model results can be found in the paper.

The main outputs of the model were the simulation of the effects of improvements in rail services, different relative prices between train and truck (Fig. 5.6A), and optimal pricing strategies for rail (Fig. 5.6B). In addition, the port hinterlands for Bahia Blanca and Quequén and elasticities were estimated. The full estimations and results can be seen in the study by Tapia et al. (2019).

## 7. Discussion

The systematic collection of tax records brings a structured and consistent database about the “footprints” of the economic transactions. These footprints correspond to the interaction between individual companies, and they dictate the economic relationship between the organizations that will derive in a freight flow.

The disaggregated (i.e., at an individual level) nature of the data brings opportunities and challenges. The opportunities revolve around obtaining good quality data for aggregated (e.g., OD matrices by aggregating the individual records) and specially disaggregated models (such as disaggregated mode choice). However, there are several challenges to be faced to make these data adequate for modeling.

The main challenge comes from the nature of the data: taxation. As they are fiscal data, before the data are available for modeling, they have to be anonymized to secure fiscal secrecy. The way that this is done has a direct influence on the models that can be used.

Within the restriction of fiscal secrecy, there are several levels of details that the data can have. The first level is obtaining aggregated data. The aggregation can be at a regional level (district, cities, provinces, etc.) and/or at a product level (can range from category of products or bundled in commodity types). This level of aggregation does not allow the modeler to use disaggregate models, but it does provide quality and trustworthy information of OD matrices and can potentially be used for aggregated distribution and allocation models. If there are previous demand models that use RP data, the new fiscal data can be used for recalibrating the models for the current modal shares. It has to be noted that flows that are unique for a company (i.e., only company of the commodity type in an area) can be omitted from the aggregation because it would violate the fiscal secrecy. This concern is shared by all levels of details.

The EI used in the PELT-Rio Grande do Sul presented in this chapter belongs to the first level of aggregation. The main application for the data was for building reliable OD matrices, but the application of behavioral choice models was limited and needed additional information to calibrate the models. The data were given at a higher level of aggregation than the open needed for the application. This meant that complementary studies needed to be done to obtain the level of detail required for the objectives of the PELT.

The second level of detail that can be obtained is removing the involved organizations in the transactions but showing the individual records. This allows to model actual flows in a disaggregated manner, for example, for a behavioral modal choice model. It is also easy to move from this type of individual data to the aggregated models mentioned before. Although it is a very interesting source of usually elusive disaggregate data, the lack of knowledge of the companies brings some limitations of the models: there is no knowledge of successive choices of the same company. This makes that any chained sequence of choices reflected in different documents are lost, together with possible changes in preference with time.

The CB belongs to this type of information. The data involved consist of the records of agricultural goods with the receiver, carrier, and shipper cropped. To solve the problem of chained choices, relevant to the choice situation here, the merging of the records commented in section 5.3 was made. It is worth noticing that this merging was able to be made because of the particularities of the tax instrument, and it is not really clear whether it is applicable in EI type of data.

The third level can involve more information on some of the companies involved by sampling and to give panel data from some of the companies and anonymized information for the rest. The panel data from companies must have an alias to maintain the secrecy and come from commodity groups and areas that make the individual identification impossible. Thus this additional level of detail is likely to appear in places with more density of producers of a certain good. Unfortunately, no study was found that uses these types of data.

Trust and cooperation between the taxing agencies with the modelers are crucial to determine the level of detail of the information. Models with tax data tend to appear after a collaboration with a governmental agency that can interpret and process the data itself or in collaboration with the academic or private sector. Moreover, the more the detailed the information is, the more responsibility and work does the tax agency has. In this subject, it is important that the modeling part is aware of the data structure and limitations and that it is specific with the data requests: the tax agency is the party with the highest responsibility and liability with a minimum reward for the results of the modeling. In all cases, data protection protocols are crucial to ensure that the data are used for the intended purpose and for the authorized parties.

To develop up this last item about the collaboration with tax agencies, the following recommendations are suggested:

- Establish the strategic importance of the models, have clear the objectives of the model, and be precise on how the tax information can improve the current models. This helps to get political support from the different areas of the government and also makes the tax agency to engage with the project.
- Be specific of the data format, information source, and preprocess needed. As the tax agency has to make sure the fiscal secrecy is maintained (it is their responsibility), they are not always available to do extra data work without being explicitly asked for.
- Be ready for a lengthy process. The time from the data request to when the data are available can be long and delay the main project if no data contingency plan is considered. Moreover, this time is mainly responsibility from the tax agencies, so there is little to be done externally.
- Expect to do plenty of data cleaning and processing. It is unlikely that the tax agencies provide any refinement of the information, so it is important to include time for data processing in the project's plan.

- Communicate the results. The application and model results can prove to be of importance to establish a more continuous flow of information for updating the model or for future efforts. If an effective and fluent collaboration is made, it is possible to obtain more detailed information in the future.

## 8. Conclusions

Within all the data problems that freight modeling has encountered, the use of nontraditional data sources is an important opportunity. This is especially true for developing countries because of the lack of structured data. In many cases, there are more nontraditional datasets available than in developed countries. One example is data that come from tax revenue agencies. The main concern with this source is that because of fiscal privacy, the access to the whole dataset is limited. Nevertheless, there is still valuable information that could be extracted with some processing and data augmentation. EI and CB are the cases shown in this chapter.

The EI has been used in the estate of Rio Grande do Sul, in Brazil, to help in the elaboration of the logistics master plan. The objective was to identify the main infrastructure constraints to prioritize infrastructure investment for the next 25 years.

The EI was used to create an OD matrix. The data, processed by SEFAZ to maintain privacy, consisted of monetary flows per group of products in macro regions. The processing consisted of transforming the monetary values into volume measures to standardize it and convert them into traffic for network assignment. Additional data collection was needed to decompose the aggregated matrix into district commodity flows.

CB was used in Argentina to control the grain movement. Two uses had been reported for freight modeling. The first one consisted of obtaining the OD of all grain flows. Additional inputs involved network data and information about macro zones.

The other use was to generate a dataset suitable for the estimation of disaggregated behavioral models. Several assumptions had to be made to make it compatible for choice modeling. The first one was to consolidate multiple shipments to recreate the choice situation. Further data augmentation consisted of obtaining data about the nonchosen alternatives, such as network analysis for distances, freight costs, and times. Finally, alternative assumptions for mode availability were made.

There are several levels of details that can be obtained from tax data. They limit and determine which models can be obtained from the data and the type of extra information needed. The greater the level of detail, the greater the effort and risk of the taxing agencies. To improve the likeliness of obtaining better data, it is important to have a proper definition of objectives and strengths of the model and to obtain a high engagement of the tax agency.

Although the results are promising, there are many limitations to overcome, mainly because of the assumptions caused by the privacy protection measures taken before the information sharing. This limits the reliability of the augmented data and can induce bias into the model estimation. Nevertheless, once the first procedures for processing are established, the specification of the data needed becomes clearer. The opportunity of being more specific in future data requests or even receive preprocessed data by the tax revenue agency appears.

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Chapter 6

# Optimizing the efficiency of the future maritime transport network of Indonesia

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## Highlights

- Development of freight transport models to inform decision-making on (1) improving accessibility, (2) reducing transport costs, and (3) increasing the efficiency of container transport.
- Development of a network model using a tour-based approach where both supply and demand are represented.

## 1. Introduction

Indonesia, a large archipelago with more than 17,500 islands, about 5000 km across, is crucially dependent on maritime transport for connectivity. The population (approximately 264 million) is strongly unevenly distributed with about half concentrated on the central island of Java. Furthermore, economic activity is strongly skewed over the islands, with 60% of gross domestic product (GDP) generated on the island of Java. A national inventory indicates a total of 2155 ports/terminals, among which 32 are sizable ports (Indonesia Infrastructure Initiative, 2012). Freight transport is associated with high logistic costs. It has been estimated that logistic costs amount to 26% of GDP (Bahagia et al., 2013). For various reasons, local freight transport is considerably more expensive than international transport; it has been observed that it is less expensive to import oranges from China than local transport from inland origins. The remoteness of parts of the country poses particular challenges, where cost subsidy is required to provide affordable transport costs and basic connectivity.

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The government of Indonesia has a key objective of reducing the disparity between remote and more developed regions (Indonesian Ministry of National Development, Planning, 2014). To this end, maritime transport performs a key role in connecting the Indonesian economy and improving living conditions in remote regions of the Indonesian archipelago. Transport/logistic costs are understandably large for an economy/society spread over many islands separated by large distances over water. As a developing country, Indonesia's economic development and competitiveness are critically dependent on strategic choices for the further development of large maritime networks. Motivated by the above, key government policies related to maritime transport include:

- efficient delivery of national, subsidized sea transport (the Perintis ferry system).
- identifying strategies for the reduction of transport costs and improvement of international connectivity.
- Reduction of disparity by means of improving the accessibility of remote regions.

The objective of this chapter is to present the recent modeling work undertaken to support these policies. The modeling centered around the optimization of the maritime network of Indonesia. It required the development of a full maritime freight demand and supply model system. The results of the modeling work were promising: it identifies significant efficiency improvement potentials of 27% for the ferry network and 50% for container transport.

The Indonesian maritime freight transport system was analyzed in two main segments in different studies. First, we considered the subsidized passenger/cargo ferry services (Perintis), which provide basic connectivity for mixed cargo to the entire country, including remote areas (case: Eastern Indonesia: 380 ports and 160 ships). These services mostly carry freight on trucks and packed in unit goods (not containers). In a separate study, we analyzed commercial interisland container transport networks at domestic level (case: 32 major domestic ports and 120 line connections) and including its connections at international level (worldwide: 437 ports and 800 shipping lines). The subsidized Perintis service should maximize the services for a minimum budget. In addition to the typical cost-minimization objective in commercial transport such as container transport, Perintis transport requires additional and more detailed criteria to evaluate the service. At the policy level, there is a need to evaluate the urgency of investment/subsidy by one or more indexes indicating the relative accessibility/connectivity of different places in a particular region, as well as detailed criteria expressing the quality of the service network to satisfy socioeconomic needs (frequency, access time, etc.). We used those additional criteria to design an improved/optimal network. We developed a transport model of the Perintis network based on the four-step modeling framework. We calibrated the model based on national survey data, and we applied several detailed criteria to derive a new improved service for the Maluku region (involving 47 ports and 15 ships).

Compared with international container transport, Indonesia's interisland container transport has relatively high transport costs, which contribute to high national logistics costs. These high logistics costs are because of a combination of factors, including the large distances, relatively low demand in remote regions, small ships, high turnaround time at ports, high port handling costs, low integration of logistic activities, and the imbalance in trade between central and remote provinces, that is, the empties problem (Varela et al., 2012). The outlook until 2030 has indicated a strong growth for the demand for container transport (Indonesia Infrastructure Initiative, 2012). Furthermore, there is also a trend in the use of larger ship size to increase economies of scale in maritime container shipment. These trends could potentially decrease transport costs. We have analyzed options to improve container shipping, which comprised the combination of the following:

- Changes to the shipping fleet and its service (line service and trunk and feeder routes),
- Port performance (turnaround time and handling cost), and
- Network options (corridors: trunk routes + feeders, pendulum/maritime highway, and potential new international port in the northeast).

Given Indonesia's existing freight transport systems, it is clear that the logistics of the full domestic freight transport network forms an elaborate collection of interrelated multimodal infrastructure components. Policy making on this system requires a quantitative insight into the impacts of changes in those components to evaluate proposed changes and establish priorities for infrastructure development.

The basis of the modeling is a bilevel network modeling approach, where the demand side of the transport services market is represented by origin/destination tables of freight moved per year, for a base year and a future year. The supply side is represented by a network with service schedules and prices. Demand and supply are matched using network flow (i.e., route choice and assignment) models and network optimization. Network optimization includes the schedule and topology of services and also underlying questions such as fleet composition and life cycle costs.

Table 6.1 provides an overview of the modeling tasks and tools applied in the project. It shows how different methods and software were used to address different questions. This approach with a broad set of tools allowed

**TABLE 6.1 Summary of modeling tools applied for network analysis.**

| Subject | Model development | Model application | Modeling tool | Policy relevance |
|---|---|---|---|---|
| Perintis transport | 1. Simulation of the network transport service | | Use of Omnitran commercial software | Analysis of Perintis' subsidy policy and potential for costs minimization |
| | 2. Simulation of multimodal freight transport service | | Use of Omnitrans commercial software | Analysis of the costs in the logistic chain to identify bottlenecks and priorities for investment projects |
| Interisland container transport | 3. Life cycle shipping cost | | Spreadsheet | |
| | 4. Optimization of routes and fleet composition (small network) | | Spreadsheet | Identification of an efficient shipping network design (related to sea tollway program) |
| | 5. Optimization of large maritime networks | | Custom-made software | |
| | 6. World Container Model | | Custom-made software | Analysis on the potential for Bitung or Sorong as an international gateway port in the North-Eastern part of Indonesia |
| | 7. Macroeconomic (SCGE) model (INDOTERM) | | Custom-made software | Analysis of the impact of reduced maritime transport cost on regional and national economic growth |

to address the questions at the right scale of modeling effort and integrate these visually for presentation purposes.

The remainder of this chapter is structured as follows. Section 6.2 describes the modeling applied for the Perintis services followed by the design of a future, optimized service. Section 6.3 deals with a detailed model of interisland container transport. Section 6.4 summarizes the main findings and provides recommendations.

## 2. Perintis ferry network

The Perintis transport system comprises point-to-point ferry services between two locations and so-called sea-going tours, which each provide a wider range of connectivity to a set of 10 to 20 locations. Each tour aims to

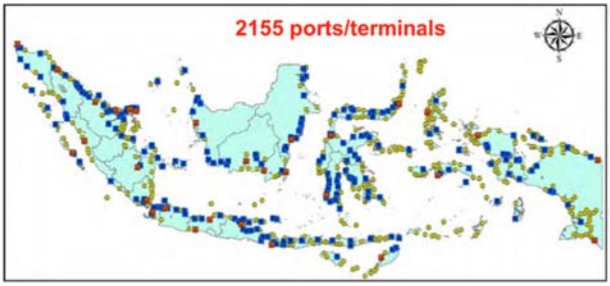


**FIGURE 6.1** Locations to be connected by Perintis within the Indonesian archipelago *(source: Indonesia Infrastructure Initiative, 2012).*

connect locations with substantial/important O-D connections while minimizing overall travel distance and contains a base station for bunkering and maintenance. A transfer to other tours at particular stations is needed to reach all locations in the network. Fig. 6.1 presents the many locations to be connected.

Designing the tours requires to identify the set of tours that provide a maximum contribution to satisfying the O-D demands, minimizing overlap. For a large set of locations and a considerable number of tours, this forms a challenging optimization problem. In mathematical perspective, this represents a very large optimization problem (network design based on multiple vehicle routing problems). In the present modeling application, a heuristic approach using simulation was chosen, which reduces the computational burden and is better suited to address the multiple criteria for the service. The subsidized Perintis service should maximize the service for a minimum budget. Minimizing costs is a dominant objective in commercial transport such as container transport; for the Perintis system, a broader set of criteria is necessary to value the socioeconomic effects of the service, which justifies the subsidy, such as travel time distribution, access time, number of ship visits and visit performance, annual costs, and total passenger miles

The present project focused on the Perintis network in Eastern Indonesia comprising a network of 380 nodes, currently served by 80 sea routes. The modeling of the Perintis network requires input of the demand for transport (O-D matrix) and transport behavior, in this case focusing on trip distribution. Data availability for estimation of the O-D matrix included:

- DGST (Department of Transport, Directorate General of Sea Transport) monitoring 2012; all voyages during the year (on average 20 voyages); full network: 80 (sea) routes and 380 nodes.
- New survey 2013–14; one voyage; partial network: 30 (sea) routes and 200 nodes.

From Directorate General of Sea Transport, 2012, the total number of Perintis passenger trips (Eastern Indonesia) is known, more than 200,000 trips in a year. The new O-D survey in 2013–14 covered 7870 trips or about 4% of the total demand. The new survey data were used to calibrate a trip distribution function. The DGST monitoring (full coverage of network necessary) was used to determine the O-D totals. Figs. 6.2 and 6.3 present the fitted distribution and the trip volume validation results, respectively. The fit with volumes observed by distance category is reasonable ($R^2 = 0.64$ for $Y = X$), but it is clear that specific distance categories perform less well than others.

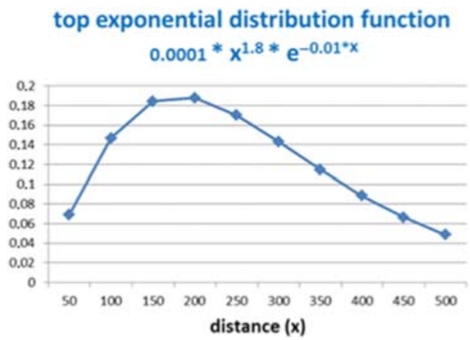


**FIGURE 6.2** Trips per distance category.

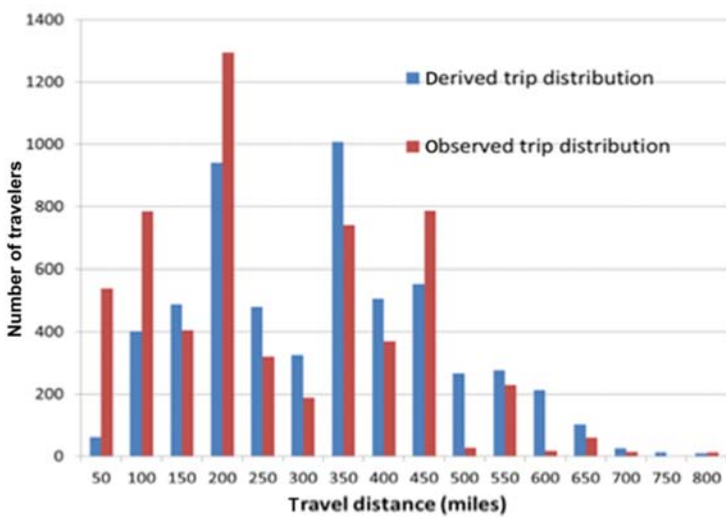


**FIGURE 6.3** Estimated trip distribution function.

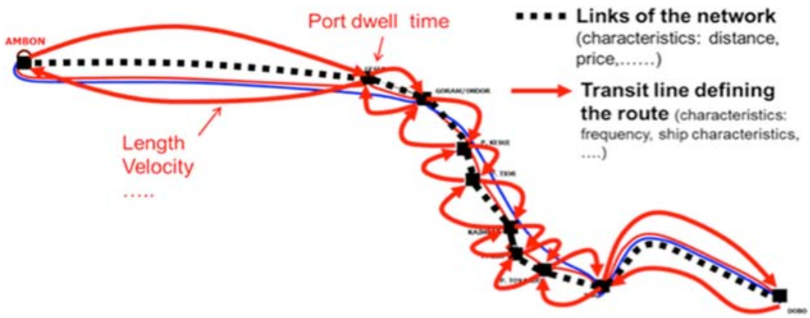


**FIGURE 6.4** Modeling schematization of a Perintis route.

Fig. 6.4 shows the schematization of a typical sea route (R31) inside the model.

The model was used to redesign a part of the network (Maluku region). Considering the criteria, the design of a new set of routes for the Maluku region has been based on judgment using a combination of concepts to design the new network. Efficiency increase was primarily driven by a reduction of the length of the current tours and a reduction of tours with overlap (fewer routes and ships). The access to base stations was kept short. In addition, we applied a hub-spoke design concept, adding trunk routes connecting hubs of circular routes, to improve overall accessibility. Finally, we aimed to maintain connections of the Maluku region with economic centers in other regions (Kupang, Reo, Sorong, Biringkasi, and Pomako).

The overall result for the new design includes benefits for the subsidizing government, the operator, and the consumers:

- a 25% reduction in the costs for operating the system,
- on average, a 27% reduction in kilometers traveled by passengers and freight, and
- a visit frequency more equally distributed among the different ports.

Fig. 6.5 illustrates the existing and the redesigned set of routes for the Maluku region. The differences are considerable, with much fewer and less overlapping lines, allowing for scale economies to be incurred in the network.

The modeling used in the Omnitrans package offers the possibility to observe/analyze the transport situation in detail along the tour by providing a loading–unloading diagram (Fig. 6.6). In addition, a relational diagram (Fig. 6.7) can be produced, indicating the importance of the available connections of a particular location to other locations in the network. The main message projected by these graphs is the scattered structure of freight volumes, geographically and volume wise.

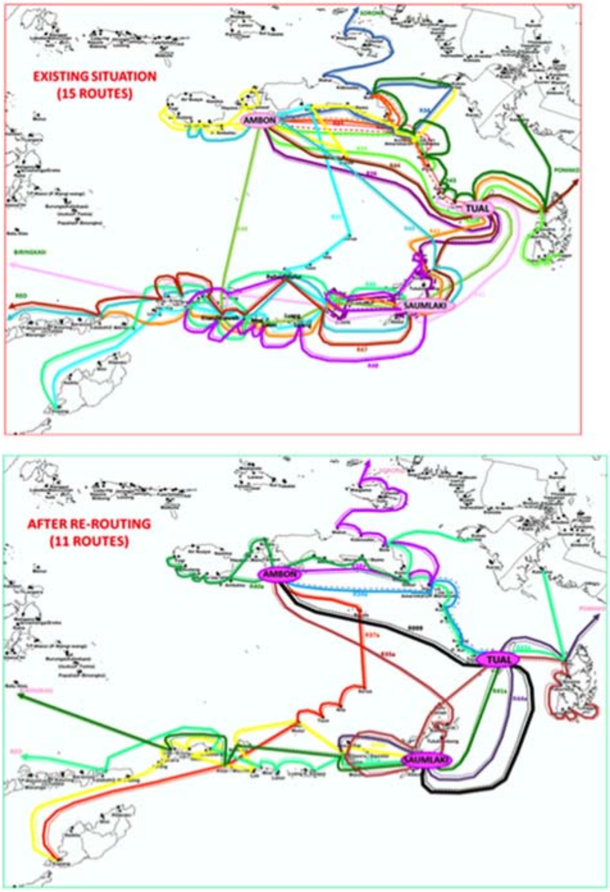


**FIGURE 6.5** Existing (l) and new (r) designed routes servicing the Maluku region.

## 3. Container transport

Different situations/scenarios for the domestic shipping service need to be analyzed to identify favorable options/conditions (Verhaeghe et al., 2016). This, in particular, relates to the expected strong growth of traffic volumes and evaluation of the potential to consolidate flows on trunks routes; both can influence cost by generating scale effects. Fig. 6.8 presents the schematization of the logistic chain used in the present modeling analyses of the interisland freight transport service.

Below, we discuss the specification of the network cost model (section 6.4.1) and the optimization of the network (6.4.2).

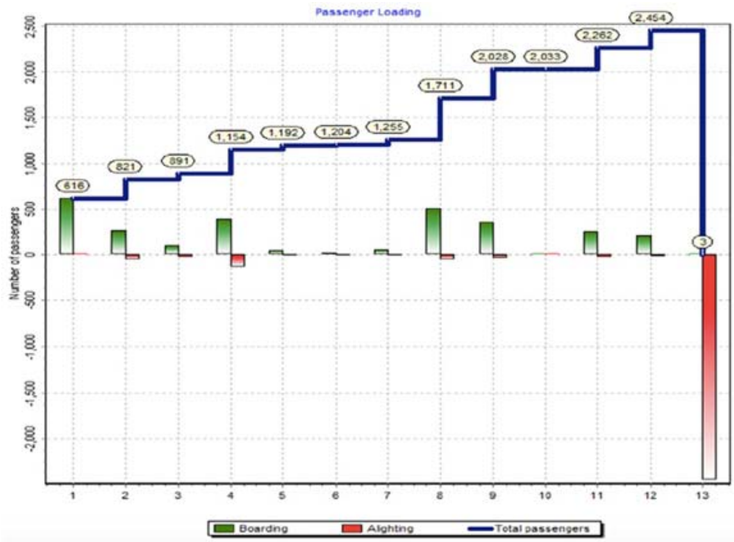


**FIGURE 6.6** (Un)loading scheme per line.

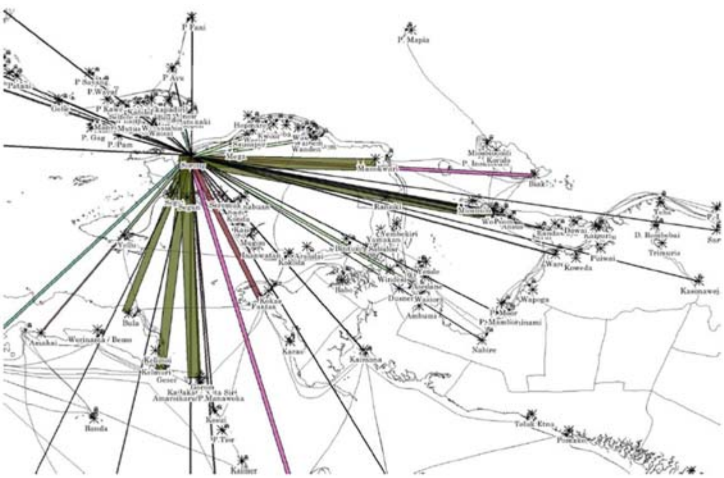

**FIGURE 6.7** Connectivity graph.

## 3.1 Network cost model

To enable computation of the costs for a variety of situations, the various components of the freight transport logistic chain have been schematized and a cost model for the shipping business has been set up. A distinction can be made between direct out-of-pocket and indirect travel time cost components.

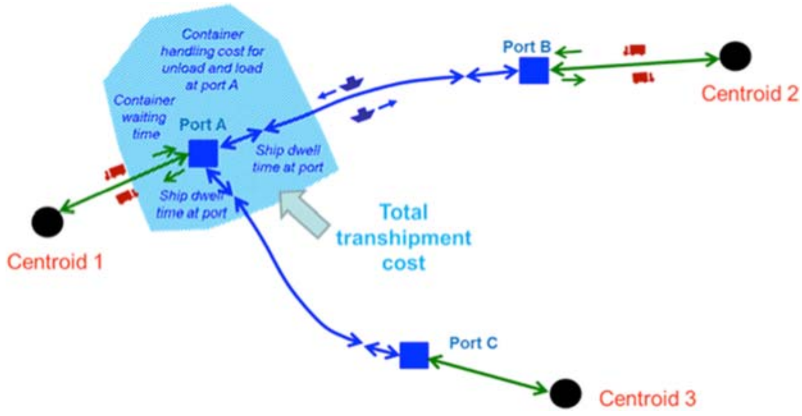


**FIGURE 6.8** Schematization of the freight transport chains.

A classical generalized cost format is considered, where transport times are weighted with a value of time and added to the door-to-door shipping rates for the cargo. The schematization differentiates further land transport−related, port-related, and line haul costs. A shipping business cost model computes the unit cost for different combinations of ship size, distance, head- and back-haul volumes, logistic efficiency, waiting times, and factor prices related to shipping operation. The life cycle cost for shipping refers to the price that should be charged (lease cost) by the ship owner/operator to cover all variable and fixed costs during the lifetime of the ship. The handling costs at ports refer to all costs associated with the handling of the cargo in ports.

The most varied cost relates to the value of time; this is applicable to all time components in the logistic chain. Assessing the time value for the transport of passengers or freight forms an integral part of a transport analysis. It refers to the opportunity value of the time lost in the transport process. For freight, this opportunity value relates to the resources that are tied up in the transport process and the opportunities lost (market expansion, consumer confidence, loss of productivity, etc.) because of slow transport. The time value is strongly dependant on the type of commodity. It relates to the cost of capital tied up in the cargo and relates further to items such as the benefit of a tighter scheduling (e.g., saving in labor costs), influence on spatial concentration of the business, opportunities for market expansion, and consumer valuation represented by the clients' willingness-to-pay for having goods earlier available. In the present study, a unique time value was adopted for all transports.

To compute the unit cost for container transport on a particular trajectory, the total annualized cost for operating a particular ship needs to be allocated to the effective payload of that ship during the year. The time during the year that payload can be carried is limited by the time needed for maintenance and the inefficiencies in operating the ship. Such inefficiencies may be because of shipment of empty containers, waiting time for load in ports, and the repositioning of the ship to pick up load. Fig. 6.9 illustrates the process of allocation of total annual cost, for the operation of the ship, to the effective payload.

The portion of annual costs allocated to a particular trip is determined by the ratio between the total time needed for the trip and the total time effectively available during the year to make payload trips. It is clear that a large turnaround time at ports strongly limits the number of trips that can be made and thus can strongly increase the allocated fixed cost per unit of payload. From the analysis of existing shipping processes and deducting nonproductive shipping time and nonoperational time from total lifetime, an overall efficiency of 65% was derived. Note that this efficiency will differ for inbound and outbound trips because of the trade imbalance between the central and remote regions. The inefficiency for outbound shipping will be larger than for inbound because the likelihood of no payload on return is much higher (similarly, the cost for container transport from Europe to China is about half of the cost for transport China–Europe).

To enable computation of the costs for a variety of situations, a business cost model has been set up. This shipping business/cost model is used to compute the unit cost for different combinations of ship size, distance, head- and back-haul volumes, logistic efficiency, waiting times, and factor prices related to shipping operation. Important cost items in the life cycle are capital and fuel costs. In the business model, capital cost for a particular size ship is derived using an estimated relationship. This relationship, available

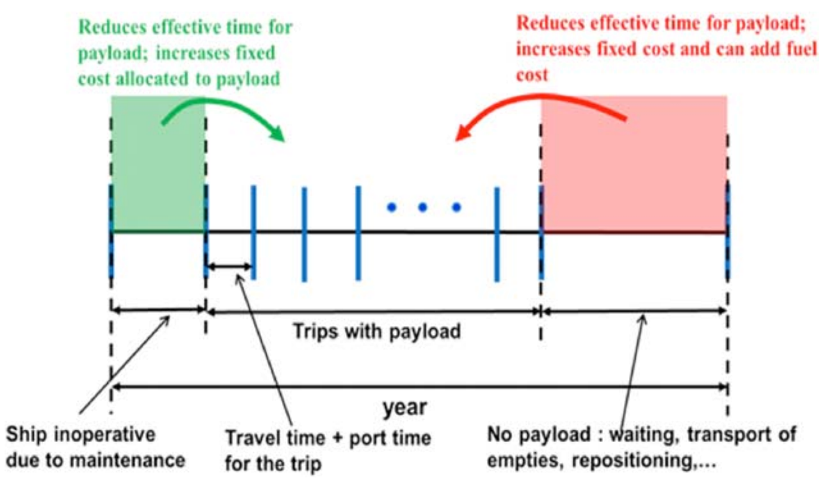


**FIGURE 6.9** Allocation of fixed costs to payload.

from literature, was estimated for a large set of ship sizes based on publicly available data (Mueller, 2014). Fuel consumption has been thoroughly studied in the function of vessel speed and size and reported in the literature. Similarly, the economics of vessel speed have been studied exhaustively. Based on large data sets, relationships have been estimated between recommended speed and vessel size and fuel consumption in the function of vessel speed and size. Such relationships have been incorporated into the business model. Obviously, if the intention is to analyze unit cost in the function of vessel speed, then this recommended vessel speed should be replaced by the relevant alternative speeds.

The input data for the business model are presented in Table 6.2 below.

Different (future) situations/scenarios for the domestic shipping service were analyzed to identify favorable options/conditions. This, in particular, relates to the expected strong growth of traffic volumes and their effect on costs. By using larger ships, one can take advantage of potential scale effects brought by overall volume growth. Fig. 6.10 illustrates an application of the cost model showing the scale effect of transport between Tj Perak and Jayapura (total flow between the ports 150,000 TEU/year); a strongly decreasing cost can be observed for larger ship sizes. The figure also illustrates the cost increase associated with an imbalanced transport (head-haul 100,000 TEU and back-haul 50,000 TEU).

Service frequency has a substantial impact on the design of the service: to transport a given volume of freight, a larger ship size will result in a lower frequency; a trade-off needs with scale effects in transport will be made. Following the classical Economic Order Quantity concept in logistics, the optimal shipping size is defined by the marginal cost for inventory being equal to the marginal cost for shipping. Fig. 6.11 illustrates for an example connection (Tj Priok-Pontianak for the projected demand in 2030) the

**TABLE 6.2 Cost model data used (typical values).**

| Input (unit) | Value |
|---|---|
| Auxiliary costs (%) | 4 |
| Salary cost ($ per year) | 80,000 |
| Fuel cost ($/ton) | 850 |
| Administrative overhead (%) | 5 |
| Profit (%) | 10 |
| Maintenance (days/year) | 15 |
| Time efficiency (%) | 65 |
| Value of time ($/TEU.day) | 50 |

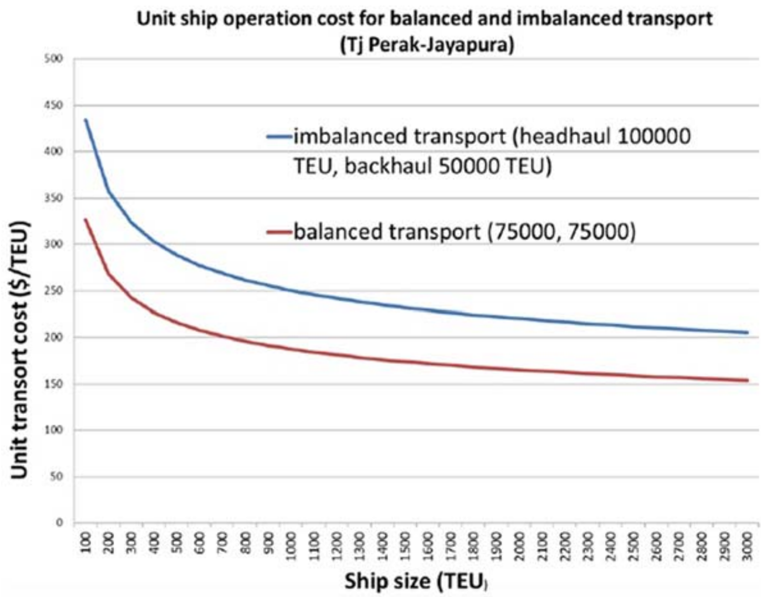


FIGURE 6.10 Illustration of scale effect in maritime container transport—effect of imbalance.

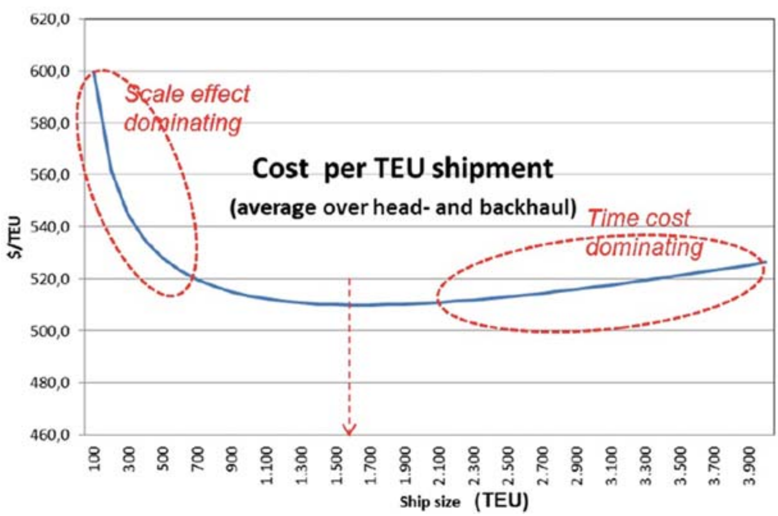


FIGURE 6.11 Trade-off between scale effect and time cost to determine optimal vessel size and service frequency.

trade-off between scale effect associated with a larger ship size and increasing time cost, resulting in an optimal ship size: tracing total transport cost (shipping cost plus time cost) for different sizes of the ship indicates a minimum cost (MC) for a size of 1600 TEU. This means a service frequency of 363 trips in a year or a daily day service, carried out by seven ships of 1600 TEU.

## 3.2 Network optimization

Strong (projected) growth of freight transport and consolidation in freight routes offer the potential for cost reduction through scale effect, as well as improvements in factors such as port handling (handling time and cost) and overall logistic efficiency. Strongly different effects can be expected in different parts of the network.

To identify the most promising opportunities for cost reduction, the year 2030 has been chosen as target year for a proactive planning with a projected demand for freight transport and potential improvements to the logistic system. The aim has been to determine the optimum fleet composition and optimal routes for the year 2030, accounting for the strongly different unit costs for different parts of the network. The optimization problem was tackled using three approaches (interactively used):

1. Manual search for opportunities for route consolidation: using some practical observations, likely candidates for route consolidation were identified.
2. Simulation of the full network: this allows to observe details and produce statistics on the total network.
3. Application of a mathematical optimization model to confirm the potential of route consolidation for the entire Indonesian domestic network, including global container flows.

We discuss these directions in more depth below.

### *3.2.1 Opportunities for route consolidation*

Fig. 6.12 presents an example network (80% of all ton.km in the Indonesian network), which has been used to explore options for a multiple port call or pendulum service between the ports of Belawan-Tj Priok-Tj Perak-Makassar. At present, practically, all trips are point to point. The performance of a potential multiport shipping line in combination with hub formation has been compared with a point-to-point shipping situation. Fig. 6.12 illustrates the multiport route between Belawan-Tj, Priok-Tj, and Perak-Makassar; the different links carry the largest flows in the network.

The detailed logistic costs for the point-to-point network and the multiport network have been analyzed in a spreadsheet and traced for combinations of different ship sizes and service frequencies. The analysis was carried out for the projected 2030 demand, assuming an improvement in ship turnaround times and container handling costs (to 2 days and USD 100/TEU,

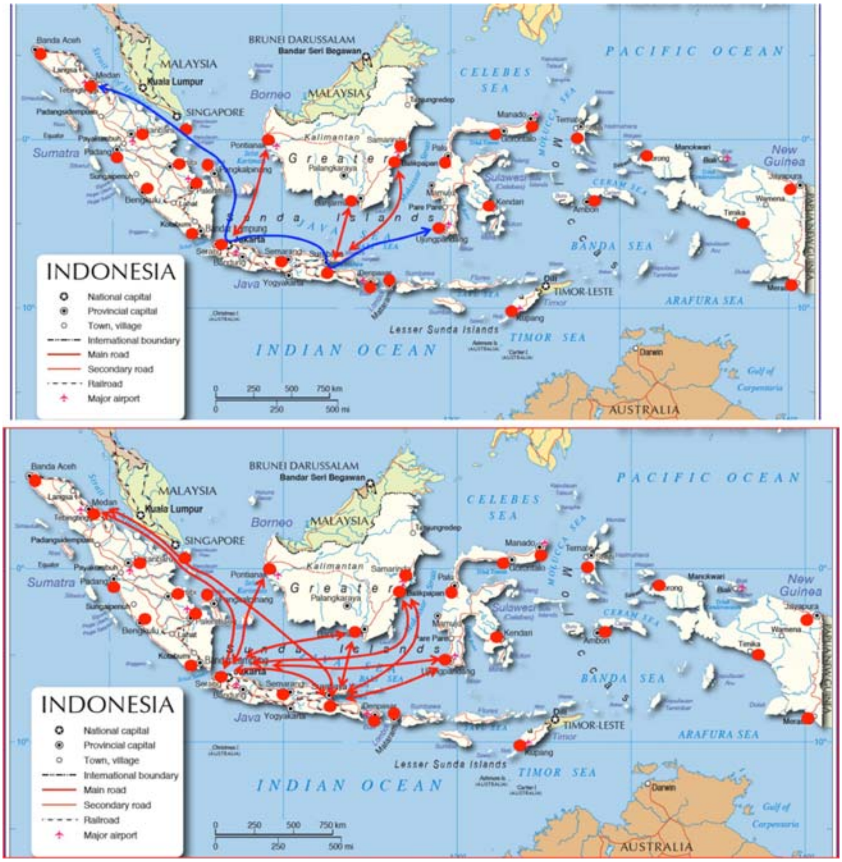


**FIGURE 6.12** Point-to-point (left) versus multiport network (right) for West + Central part of the country *(source: Adapted from Nations Online Project).*

respectively). Fig. 6.13 compares the optimal ship sizes for the multiport trunk system and the optimal point-to-point ship sizes for the three routes between the four hubs.

It can be observed that the multiport call system is slightly more expensive (4470 million dollars per year vs 4431 million dollars per year for point-to-point shipping). Apparently, the savings because of consolidation and scale effect are canceled out by the increased transshipment costs. Furthermore, one size ship is not the best fit for the individual trunk routes; the point-to-point option provides the flexibility to adapt the ship size to the flow distance characteristics of the particular stretch and, in this way, reduces costs. A multiport call service will also be more sensitive to disturbances.

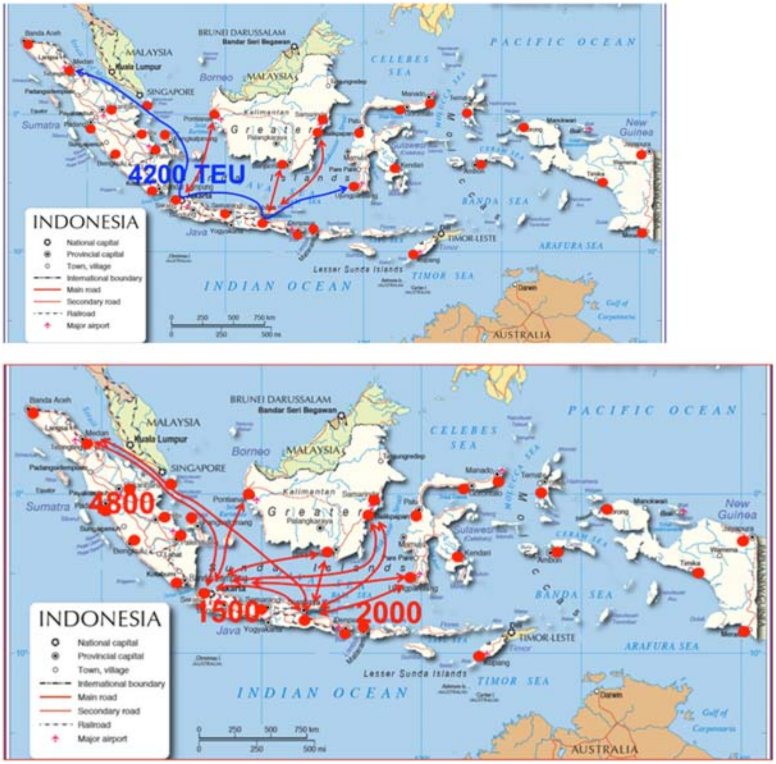


**FIGURE 6.13** Optimal ship size for the multiport trunk system and the optimal point-to-point ship sizes for the three routes between the four hubs *(source: Adapted from Nations Online Project).*

Another important aspect of the network design problem is the connection of the central part of the network to the remote eastern part. Fig. 6.14 illustrates a set of point-to-point connections to Eastern Indonesia from the port of Surabaya, presently the major gate toward the eastern part of the network. A consolidation scenario was investigated with a hub function for the port of Ambon. Fig. 6.14 illustrates the optimal ship size for the Tj Perak-Ambon connection for the case of Ambon hub and point-to-point connections.

A considerable scale effect can be realized in the Tj Perak-Ambon route by consolidating the eastern flows to Tj Perak, however, the transshipment costs at Ambon dominate by far the scale benefits. The total system cost for the Ambon hub system was at 762 million dollars per year and for the point-to-point shipping system at 464 million dollars per year.

These tests to consolidate flows in trunk routes to create scale effects, as elaborated above, indicate that, for the expected conditions up to 2030, a

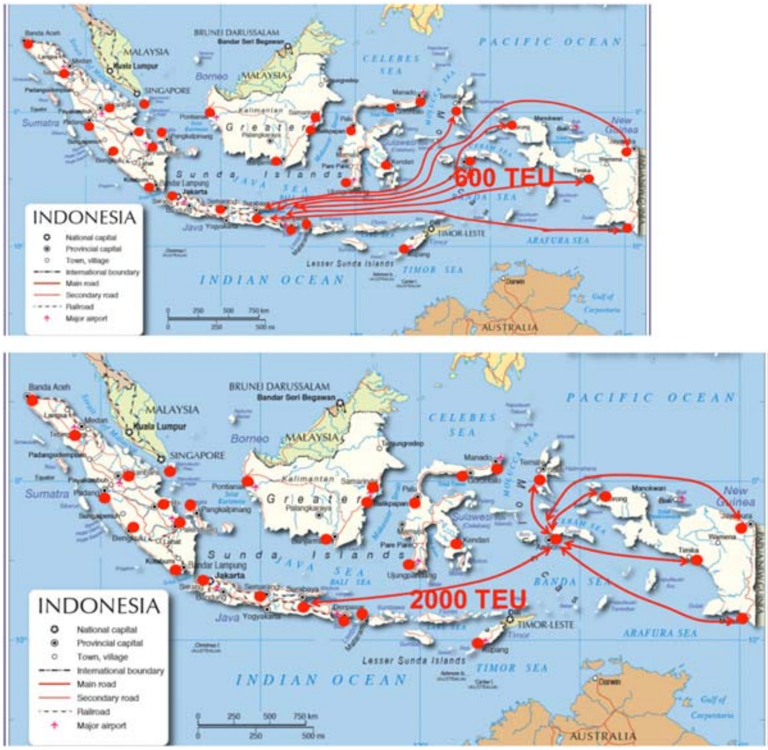


**FIGURE 6.14** Comparison of the optimal ship size Tj Perak-Ambon for the Ambon hub system and the point-to-point connection *(source: Adapted from Nations Online Project).*

point-to-point network will be the MC service network. The main reasons for this are the strongly varying flows in different parts of the network and relatively high transshipment costs.

Following the above, the network costs were determined for 50 point-to-point connections covering 95% of the flow in the network. The results show a large variation in unit transportation cost (\$/TEU.km) for the different connections (Fig. 6.15). The weighted average cost is 0.073 \$/TEU.km.

### *3.2.2 Simulation of multimodal freight transport service*

A simulation model has been set up, which addresses in detail the logistics, as elaborated above for all routes in the network. The modeling incorporates the multimodal transport flows; in the current schematization, the land phase transport has been simplified, it considers only a truck-based direct route from the major city of the different transport regions to the relevant port(s). The present model considers 32 ports, which serve 36 transport regions (represented by a centroid) in which freight is generated or consumed. At present, those 36 transport regions

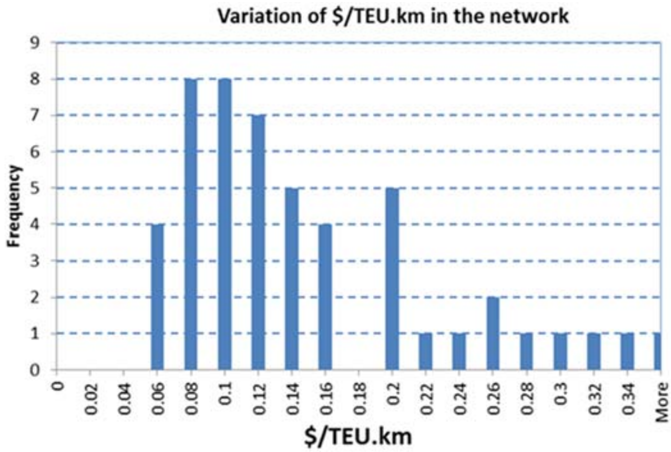


**FIGURE 6.15** Variation of shipping cost in different parts of the network.

correspond to the provinces (or parts of). The input to the model consists of a set of existing or proposed service lines characterized by a route (covering more than two ports in case of multiport routes), ship size, service frequency, and cost data (provided by the cost model), and the O-D matrix for containerized freight. The Omnitrans transport software is used to handle the very large database; which describes the logistics of the total network, to compute the performance of the network; and to present results in particular formats. The software allows to present the performance results of the particular simulated service network in a variety of ways (maps, graphs, and tables), such results are illustrated below.

Information on internodal transport is contained in the O-D matrix. A graphical presentation can be very helpful in illustrating these relations. Fig. 6.16 illustrates the strongly centralized transport flows for three nodes (Sorong, Ambon, and Bitung) with very strong connections to Java and hardly any connection to other nodes.

Fig. 6.17 illustrates the loading of the network resulting from this proposed service network. Table 6.3 presents port statistics (loading, unloading, and transshipment) associated with the simulated transport system.

The simulation model keeps track of the loading, unloading, and transshipment of the containers for the simulated flow pattern. Fig. 6.18 presents a graphical image of the throughput at the various ports.

The optimal (least cost) network for 2030 was derived as a set of point-to-point connections, for each of which an optimal size and frequency shipping have been determined. The optimal network is served with 216 ships with sizes up to 5000 TEU. The distribution of the load to different ship sizes, for 2013 and 2030, is presented in Fig. 6.19: a considerable part of the load is carried by the larger ships.

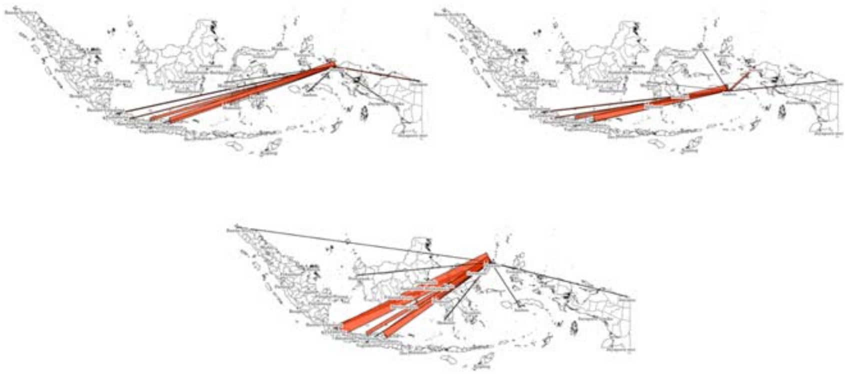

FIGURE 6.16 Transport patterns for three regions.


FIGURE 6.17 Loading of the network.

**TABLE 6.3 Comparison existing (2013) and upgraded 2030 container service.**

| Service attribute | 2013 | Upgraded 2030 |
|---|---|---|
| Total load (million TEU) | 3 | 14 |
| Average (out-of-pocket) cost ($/TEU) | 646 | 302 |
| Average load factor (%) | 47 | 80 |
| Time efficiency (%) | 65 | 90 |
| Number of ships | 455 | 216 |
| Ship turnaround time (days) | 4 | 2 |
| Container handling cost ($/TEU) | 150 | 100 |


FIGURE 6.18 Throughput of the different ports.

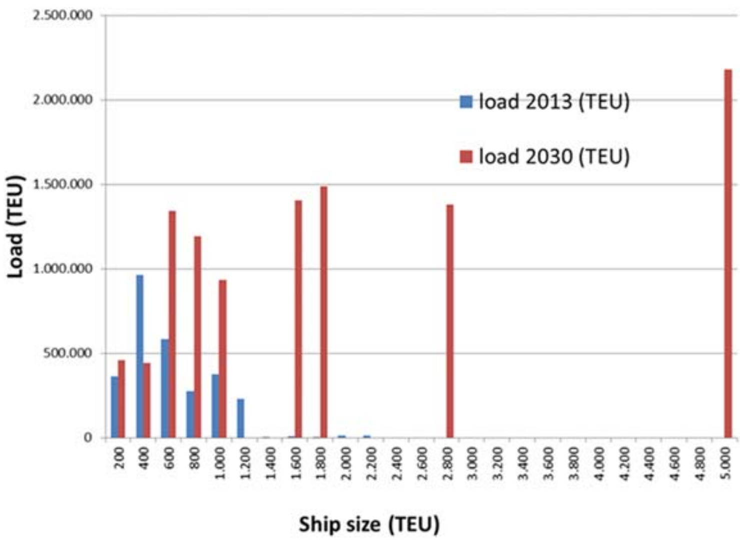


FIGURE 6.19 Load distribution to different ship sizes for the existing (2013) and 2030 situation.

Overall, a strong reduction ($>50\%$) of (out-of-pocket) transport cost appears possible in the future (2030); this is based on the scale effect of fleet size and mix adaptations and improvement of logistic efficiency. Table 6.3 compares the main parameters of the 2013 existing situation (shipping costs computed with the cost model) and the 2030 scenario.

The composition of out-of-pocket costs, comprising ship operation cost and port handling, is expected to change drastically in the future. Both costs (average over the network) are estimated at about 50/50 at present; in the future, this is estimated to change to ship 1/3 versus port 2/3. In the longer term, port handling cost is expected to dominate the transport cost (on average for the Indonesian network). This puts emphasis on the important role of improving ports in the upgrading of maritime transport.

### 3.2.3 Network optimization

To identify potential future shipping networks in Indonesia, we also applied a network optimization approach, which is elaborated in detail in the study by Halim, 2017. This approach allows to find networks with an optimal realization of consolidation and scale effect based on the potential network structure(s), the trade (O-D) pattern, and transshipment costs. We formulate this service network design problem as a biobjective optimization problem in which (1) transportation user costs and (2) total network distance are minimized as two independent objectives. Network distance is taken as a proxy for operation costs. The model then can be used to study the trade-off between sparse and dense networks, where the first has low operation costs but high user costs, opposite to the second. The model used here is a generalized network design problem, also called the MC network design problem or fixed charge design problem (Gao et al., 2005; Magnanti and Wong, 1984).

The output of a multiobjective optimization model is normally a set of solutions that are optimal in terms of both costs. That is, there is not a single solution within the set that is superior to other solutions in both objectives simultaneously. This set of optimal solutions is called the set of nondominated solutions. Within the objective space that is defined by both T and Z values, the nondominated solutions form a frontier, which distinct these solutions from the suboptimal solutions behind the frontier. This frontier is called the Pareto frontier, where each of the nondominated solutions represents a certain maritime shipping network structure that has distinct T and Z values. The set of Pareto-efficient or nondominated solutions are useful to exclude a large number of network designs for which there are always better alternatives, irrespective of the relative importance one attaches to the two objectives. In addition, it helps to choose a specific network structure once the relative importance is known.

Fig. 6.20 shows the visualizations for port networks based on the nondominated solutions for MC network. In this network, independent of the weighting of the two objectives, a shipping corridor that resembles a trunk route appears to emerge. This corridor connects major ports from the Western to the Eastern regions such as Belawan, Tj. Priok, Tj. Perak, and Makassar with the least distance. Smaller ports are connected to this main trunk route via the closest hubs in the region. Because there are not many alternative routes between ports, transport flows are concentrated along the main trunk routes along the coast of Sumatra, Java, and Makassar.

To investigate how designs of the domestic network could provide synergies with global flows, a simulation of international flows was carried out. For illustration purposes, we compared Bitung and Sorong as alternative international hubs on the national network. The calculations were done using an existing global container flow model with data for trade in 2030 (Tavasszy et al., 2011). The results for international flows are shown in Table 6.4.

Although the results of both potential hubs are very similar for international flows (each would capture about 5% of the total for Indonesia),

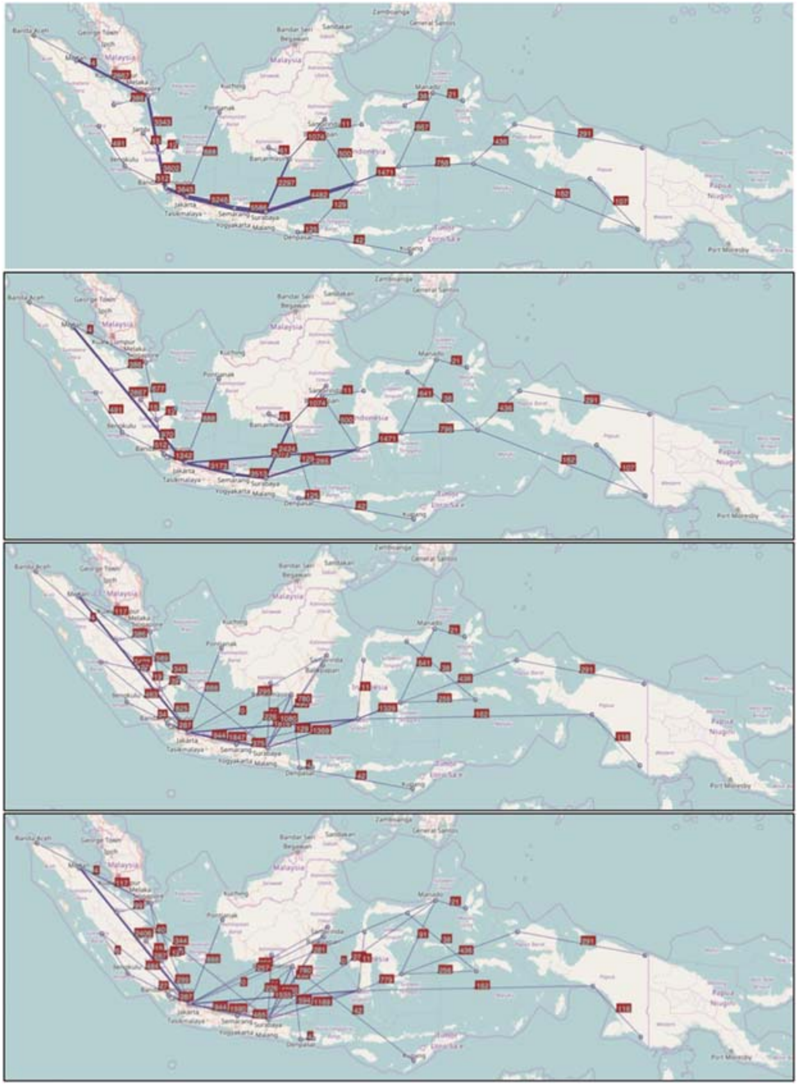

**FIGURE 6.20** Alternative optimal networks ordered from sparse (top) to dense (bottom).

international flow through Sorong could better be combined with domestic flows to create an additional scale effect for flows from Eastern Indonesia (Fig. 6.21).

## 4. Conclusions and recommendations

Maritime transport is crucially important to the Indonesian archipelago to provide socioeconomic connectivity. Many options need to be analyzed to

**TABLE 6.4** Simulated international flow (2030), including Bitung and Sorong alternatives.

| Bitung as a hub | | | Sorong as a hub | | |
|---|---|---|---|---|---|
| **Port** | **Total throughput (TEU)** | **Fraction from international flow (%)** | **Port** | **Total throughput (TEU)** | **Fraction from international flow (%)** |
| Bitung | 1,684,808 | 5.6 | Sorong | 1,508,040 | 5.1 |
| Tg Perak | 8,718,388 | 29.2 | Tg Perak | 8,653,203 | 29.2 |
| Tg Priok | 16,357,363 | 54.8 | Tg Priok | 16,406,638 | 55.3 |
| Tg Emas | 481,093 | 1.6 | Tg Emas | 479,392 | 1.6 |
| Belawan | 2,598,496 | 8.7 | Belawan | 2,615,310 | 8.8 |
| Total international flows | 29,840,150 | 100 | | 29,662,582 | 100 |

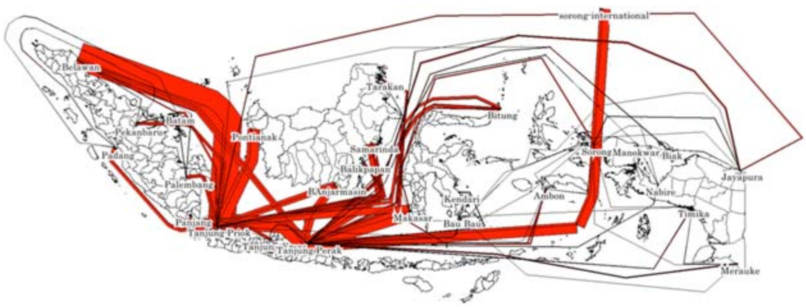


**FIGURE 6.21** Indonesian container shipping traffic with Sorong as international hub.

arrive at a robust design of network improvements that support the future development of the economy. Modeling tools will be very useful to oversee and investigate these options.

Our research on improving the design of the Indonesian maritime freight network addressed two main segments: the national ferry system for passengers and mixed cargo, as well as the (national and international) container transport services.

- The modeling of the Perintis service network included a systematic analysis of options to reduce costs and improve service. Redesign for a part of the large network indicates a potential for (1) a 25% reduction in the costs for operating the system, (2) a 27% reduction in kilometers traveled by passengers, and (3) a visit frequency more equally distributed among the different ports.
- For container transport, we used different modeling tools for a systematic exploration of cost factors and design options. It involved analyzing current and future (2030) flows, composition of the shipping fleet, explicitly taking into account the role of distance, size of demand, shipping size, port performance, logistic efficiency, and network options, in the design of improved transport options. The various analyses indicate that a strong reduction (50%) in total transport cost is possible for the horizon year (2030), the realization of scale effects based on an upgrading of the shipping fleet, and the implementation of port performance improvements. Such a reduction is not only possible for the overall domestic network but also for transport to Eastern Indonesia.

The present modeling effort can be further expanded to improve and expand the potential to carry out evaluations of the national maritime network. The following can be mentioned:

- Development of a new national transport model for 443 Kabupaten, 60 ports, the maritime and land network including the associated database as standard for transport studies.

- Harmonized monitoring and database and model development: models provide a systematic link between database and planning/policy analysis.
- Improved/detailed O-D transport demand estimation, linked to socioeconomic data.
- Improved estimation of the structural effect of transport on the economy.
- Expanded multimodal transport analysis to include distribution centers and logistic hubs.
- Applications to optimize the total Perintis network, elaborating potential linkages with commercial transport.
- Applications for capacity requirements for Indonesian seaports, taking into account both national and international freight flows.

The approach of the analysis can be transferred to different archipelagic countries that rely heavily on local, domestic, and international shipping services for their internal connectivity. Specific circumstances such as cost structures and wage levels, ship types, distribution of ownership over fleets, and the uneven distribution of the population and industry call for special care during transfer toward different contexts than the Indonesian, in particular of the empirical findings. Several insights, however, should be broadly applicable. These include the crucial role of passenger and mixed-use ferries for industry, the possibility for local goods movements to piggyback on international lines, and the resulting necessity for joint optimization or alignment of schedules of these subsystems.

## Acknowledgements

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Chapter 7

# Evolution of logistics and modeling findings in the era of economic crisis in Greece

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## Highlights

- Develop efficient added value logistics services in Greece, which is now emerging from economic crisis.
- Mode choice model development.

## 1. Introduction

Logistics is a vital and essential function for all types of organizations, while only recently its importance in the rationalization and efficiency of economic and production processes have been acknowledged in Greece. Greece's financial crisis that followed the world economic crisis of 2008–09 led to high unemployment rates, decreased investments, and decreased demand for services and products. In this context, companies had to pay closer attention to their costs, functions, and performance to ensure that they will survive. Both public and private entities invested in optimizing their operations through logistics and supply chain management techniques. Mitsakis et al. (2013) while studying the effect of the economic crisis on the transport sector of Greece found that the crisis did not have the same effect on all transport modes. More specifically, it seems that the logistics and maritime sector remained unharmed, whereas road transportation appears to be the recipient of the recession negative impacts (reduced tons, ton-km, and volume of containerized cargo). The latter is also supported by a recent study of Moschovou and Tyrinopoulos (2018) who found that the freight volumes in Athens and Thessaloniki were reduced by 42% in comparison to 2008. Their research also proved a direct relationship between the performance of the urban road transport and the

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country's gross domestic product (GDP). According to European Commission (2019), the wider transport and logistics sector in Greece is now considered as one of the most important sectors of the Greek economy, contributing 10.85% to the domestic GDP, whereas based on the World Bank rankings (2018), Greece is ranked 47th for its logistics performance, with significant growth prospects. One of the core activities of logistics concerns the movement of materials and products across the supply chain, where the choice of transport mode is considered to be the most critical one. To this end, the aim of this chapter is twofold: (1) to provide insights on the logistics sector of Greece before and during the financial crisis through secondary research and (2) to develop and present a freight mode choice model for Greece. In addition, through the model investigation, this chapter tries to assess to what extent the economic recession has affected the values of time for freight transport modes. The initial hypothesis of the authors is that the financial crisis in Greece has led to a decrease in freight value of time (FVOT) observed in all transport modes.

The freight mode choice that is presented is one of the components of the national transport model developed under the wider project "National Transport Plan for Greece." The project, by its terms of reference, essentially focuses on the passenger transport model. Therefore the available resources for the "freight component" were reduced, as well as expectations for an extended disaggregate data collection and detailed analysis of the freight model. The whole project was financed by European Investment Bank (EIB) and conducted by an international Consortium led by Egis. It was accomplished in 2019.

This chapter is composed of six sections. Section 7.2 presents the literature review on freight mode choice and value of time (VoT). Section 7.3 presents the research approach. Section 7.4 provides background information. Section 7.5 presents the model estimation results and the VoT. Section 7.6 concludes the chapter by discussing results, policy implications, and future research directives.

## 2. Literature review

VoT has been studied extensively since the early 60s, focusing mostly on the substitution rate between travel cost and travel time for passenger transportation. The number of studies regarding the FVOT or value of freight travel time saving (VFTTS) are considerable fewer and rather limited. This section aims to provide a comprehensive presentation of existing studies on FVOT or VFTTS.

Zamparine and Reggiani (2007) conducted a meta-analysis for VFTTS using observations derived from a sample of empirical VFTTS from North, Central, and Southern European countries, as well as North America. While analyzing the data, it became evident that there is a remarkable variation among the estimated VFTTS from the different studies ranging from 0.8 to

47.2 per hour US$ (in 2002 $). In addition, they found that the VFTTS values in northern Europe are considerably lower than the ones observed in Central and South Europe, whereas VFTTS for road transport is significantly higher than the VFTTS for rail transport. Similar results were also found in the studies by de Jong (2008) and Feo-Valero et al. (2011) while reviewing the VFTTS estimates for road transport in a number of EU countries (Norway, Sweden, UK, Netherlands, Germany, France, Denmark, Finland). The majority of the studies report values ranging from 30 to 50 Euros per hour (in 2002 Euros) and takes into account the operational and other costs (e.g., capital cost of the cargo in transit). Feo-Valero et al. (2011) while reviewing FVOT studies for all transport modes in Europe reported an enormous variation of obtained FVOT. In addition, they observed that the FVOT for road is significantly greater than the FVOT obtained for rail and shipping modes. These findings are also supported from previous studies that compared the FVOT of different transportation modes (Zamparine and Reggiani, 2007; Beuthe and Bouffioux, 2008; Russo and Chilà, 2007).

The literature for VFTTS and FVOT for other transport modes, such as rail, short sea shipping (SSS)/maritime, and air, are rather limited. García-Menéndez and Feo-Valero (2009) estimated that the FVOT for maritime transport in Spain is 26.05 Euro per hour per shipment, whereas Bergantino and Bolis (2008) estimated that the FVOT for maritime transport in Italy is, on average, 55.65 Euros per hour per shipment. Concerning rail, de Jong et al. (2014) estimated that the FVOT for a full train is, on average, 1100 Euro per hour, whereas Russo and Chilà (2007) estimated that the FVOT for rail transport is 68.55 Euro per hour.

In terms of the research approaches used for estimating FVOT and VFTTS, the majority uses stated preference (SP) data, acquired from shippers and carriers (de Jong, 2008; Duan et al, 2017). In a thorough review of studies that have been conducted for valuing FVOT, Feo-Valero et al. (2011) raised an important issue for estimating accurate FVOTs and concern the identification of the decision-maker of freight transport choices. In terms of the models developed, the key attributes that are currently taken into consideration are travel cost, travel time, frequency of service, and reliability (de Jong, 2008), whereas logistics-related variables are also considered important (de Jong and Ben-Akiva, 2007). A more recent study by Duan et al. (2017) discussed the heterogeneity of FVOT and the importance of taking into consideration while designing a service network.

As it can be seen, the number of papers available in the literature dealing with FVOT and VFTTS is limited with the most recent one published in 2017, whereas the majority is dated between 2007 and 2011. This chapter develops a freight mode choice model for Greece to estimate the FVOT for road, rail, and maritime transport. It should be noted that this one is of the few studies that provides insight on the FVOT of the modes that currently exist in Greece.

## 3. Research approach and methods

Fig. 7.1 presents the research approach implemented in this study to achieve its objectives. Initially, a preliminary (secondary) research is conducted to capture the structure and market conditions of the logistics sector in Greece before and during the economic recession, in terms of size, geographical organization, operational performance, and infrastructure. The findings of this analysis allowed in the next step a more focused quantitative survey conducted with freight forwarders to understand the factors affecting the decision-making process for freight mode choice within Greece and estimate the VoT for the different modes. The proposed approach would allow defining new directions for a future enrichment of the freight model incorporating additional factors influencing the movement of goods and, possibly, new specifications affecting the model "philosophy."

### 3.1 Preliminary (secondary) research

The preliminary field research aimed at identifying the main structure of the logistics sector and possible ongoing-related structural changes in the country. It has been performed through interviews with representative actors of the main professional associations of freight and logistics sector in Greece, such as the "Association of International Freight Forwarders and Logistics Enterprises of Greece", the Panhellenic Union of Forwarding Enterprises, the Hellenic Federation of Road Transports, the railway operators TrainOSE, PEARL and Goldair, port authorities and terminal operators, Chambers of Commerce and Industry, and the Ministry of Transport and Infrastructure. Moreover, the collection of aggregated statistical data through the aforementioned field research allowed better understand the "magnitudes" of various components of the freight and logistics system in Greece. The whole analysis allowed depicting market issues and infrastructure and spatial location issues and identifying gaps in the sector's operational performance as well. Similarly, the results of the preliminary research allowed identifying representative actors and the main freight corridors and origin−destination (O-D) pairs based on which we defined the sample for the implementation of the primary quantitative survey and collected appropriate disaggregated data.

### 3.2 Primary quantitative data

The collection of primary quantitative data was conducted through a survey tool and included both revealed and SP questions. Revealed preference (RP) data provides useful information on the existing choices and patterns of the survey respondents, whereas SP data are flexible data that can describe hypothetical or virtual decision contexts, including existing and/or proposed alternatives. SP data are rich


**FIGURE 7.1** Research approach.

in the trade-off information between the various attributes while yielding multiple observations per respondent. In this study, the SP data enabled the collection of data on decision-maker choices under different scenarios with systematic variation in mode attributes. To acquire reliable data, it is important that the respondents fully understand the hypothetical context and are committed to respond to the scenarios presented to them. Section 7.4 presents in more detail the design methodology of the SP scenarios and the data collection approach that was used.

## 4. Modeling framework for freight mode choice

The primary data collected were used to develop a random coefficient multinomial logit model and estimate the probability of a decision-maker to choose a multimodal alternative based on the random utility theory (Ben-Akiva et al., 2002). These models are widely used because they can capture taste heterogeneity among the population segments. The final utility for each mode alternative, and subsequently the probabilities of choosing it, is affected by the mode-related attributes, such as travel time and travel cost. The model developed is capturing: (1) the correlation between alternatives with common characteristics, (2) correlations among the observations of the same individual, and (3) taste variation on the travel time coefficient. For the first two, these correlations are captured through the inclusion of appropriate random error terms, whereas the latter (travel time) is considered to be a random coefficient, independent and normally distributed, imposing the restriction that the coefficient for all members of the population has the same sign and magnitude.

## 4.1 Model specification

The model consists of structural and measurement equations. The structural equation expresses utility $U$, where $U$ is a vector, whose dimensionality is equal to the number of alternatives considered ($J$). The specification of a random coefficient mixed logit model is the following (for a decision-maker $n$ choosing alternative $i$ from a choice set of $J$ alternatives):

$$U_{in} = ASC_i + X_{in}{}^*\beta + \sigma_i\varepsilon_{in} + v_{in}$$

where $\mathrm{ASC_i}$ are the alternative specific constants of each alternative i, $X_{in}$ are observed variables that relate to the alternative $i$ and decision-maker $n$, $\beta$ is a vector of coefficients of these variables, $\varepsilon_{jn}$ is a Gaussian, zero-mean error term, with a standard deviation $\sigma_i$, and $\nu_{in}$ is a zero-mean, random term that is independently and identically distributed extreme value.

The measurement equation comprises the choice model:

$$y_i = \begin{cases} 1, & \text{if } \mathrm{U_i} = \mathrm{maxj}\{\mathrm{U_j}\} \\ 0, & \text{otherwise} \end{cases}$$

$y_i$ is a choice indicator, taking the value 1 if alternative $i$ is chosen, and 0 otherwise.

The description of the coefficients $\beta$ is given in Table 7.3 where the model estimation results are presented.

# 5. Background

## 5.1 Study area

Our analysis concerns Greece, which is located in Southeast Europe and has a population of 10.7 million (Eurostat, 2019). Greece, because of its geographical location, can act as a transshipment hub connecting the Far East with Europe through its ports, road, and rail network. The transportation network of Greece is mainly road based, with more than 2200 km of motorways linking the capital with the Northern part of Greece, while ensuring connectivity with key assets, such as the Port of Piraeus and the Athens International Airport (European Commission, 2019). On the contrary, the rail network is quite sparse and significantly underdeveloped compared with other European countries; thus the freight market share for rail is really low (European Commission, 2019). Map 1 presents the location of Greece main hubs, as well as the network corridors of Greece that belong to the Trans-European Transport Network Corridors {{{Fig. 7.2}}}.

## 6. Key findings from the preliminary research for the logistics sector in Greece

The maturation of logistics concepts in Greece and geopolitical considerations about the strategic geographical position of the country as the southeast gate of Europe underline significant perspectives about an important role that the country can potentially play in international supply chains.

Regarding modal split, road transport dominates spectacularly in the internal freight market, accounting for 97.3% of all inland freight traffic (in ton-kilometers). According to recent estimations, the third-party logistics market segment represents between 18% and 23% of the total freight volume handled. The share is quite small, considering the international comparisons. As third-party logistics providers and forwarders without having a road transport license do not exceed 1000 companies in total, it can be assumed that the road transport sector includes more than 30,000 companies of various sizes, including all types of road freight transport service providers. The capital concentration of the sector is strong; the large majority of them are unipersonal enterprises. Only 0.1% of them employ more than 250 persons.

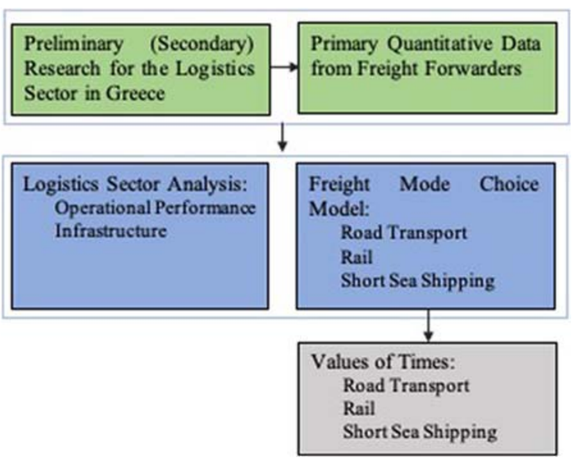


**FIGURE 7.2** Map of Greece. ***Source****: Trans-European Transport Network Corridors (https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/map/maps.html).*

Relevant figures of concentration rule the fleet distribution: there are only about 150 companies that own/operate more than five vehicles, and 5–10 companies own/operate between 40 and 50 vehicles.

The country presents a small size of third-party road freight fleet (36,495 trucks), compared with the very big size of own account fleet (1,307,335 vehicles of all sizes), reducing capabilities for economies of scale and vehicle's productivity. Among the third-party road freight fleet, approximately 4000 trucks are active in both domestic and international trade.

The logistics sector in Greece appears as a two-tier system. International logistics operators are present in Greece and, along with few large Greek companies, offer modern integrated services. They coexist with a plethora of small businesses providing limited and low value–added trucking and warehousing services. The small businesses dominate the second and third tiers of supply chains, controlling notably local distribution. The spatial organization of the companies of the sector follows the polarization figures generally observed in the economic geography and demography of the country. A strong spatial concentration of Greek logistics companies is observed, most spectacular in the regions of Attika/Piraeus (40.7%) and Thessaloniki (12.1%). Large forwarders present a strong concentration in Attika/Piraeus region.

Greece presents a much higher performance in maritime connectivity than in logistics performance and trade costs. Spectacular growth of transshipment activities in Piraeus is observed, and a larger offering of shipping connections brought by the recent development in the Piraeus Container Terminal (PCT), operated by Cosco. From 2.52 million TEUs in 2013, PCT reached a traffic of more than 5 million TEUs in 2019, becoming the first Mediterranean container port. Approximately 20% of the total Piraeus container traffic deals with import/export, and the remaining 80% being transshipment traffic. Similarly, the port of Thessaloniki presents signs of important traffic development. The Ports of Piraeus and Thessaloniki represent the two sources of container traffic generation in the country.

Greece's geographic location in the Eastern Mediterranean provides a competitive transit route for Europe's maritime trade with Asia as the transit time of a container ship from China to Piraeus was estimated to last 8–9 days less, compared with other ports in northern Europe. The PCT cooperates with railway companies, offering competitive rail freight services toward important destinations in Central Europe. This has led to the development of a competitive alternative link with Far East ports compared with North European ports in terms of transport time, service frequency, and cost.

Considering the above, a number of favorable conditions might allow the effective transformation of Greece into an integrated freight center and a European gateway for transport, by exploiting its potential. The findings of this preliminary research allowed the identification of representative actors and significant freight corridors to define the sample of the primary quantitative field survey and collect appropriate disaggregate data.

## 7. Freight mode choice and Value of Time

### 7.1 Data collection and sampling methodology

In freight transportation, a number of actors can be involved in the decision-making process for transport mode, such as the shipping firm (shipper), freight forwarders, and agents, thus making the identification of the actual decision-maker a difficult task (de Jong, 2000). The shipper, which is usually the owner of the products that need to be transported, is considered to be the most important decision-maker, who is responsible for arranging the transportation services for a number of studies (de Jong, 2000; Brooks and Trifts, 2008; Arunotayanun and Polak, 2007). On the other hand, there is also a growing body of literature that considers that key decisions that concern freight transport are taken by freight forwarders; thus they should be considered as the decision-makers (Bergantino and Bolis, 2004; Feo et al., 2008; Bergantino and Bolis, 2008). By taking into account the findings from past research, it was decided to address the survey to freight forwarders operating in Greece because the population is smaller and can provide insight for different types of products and customers.

A total sample of 100 freight forwarders participated in a computerized assisted survey that was administered through personal interviews in 2017. The survey tool was developed using the Sawtooth Software and particularly the Choice-Based Conjoint technique and collected both RP and SP data. By taking into consideration the existing transport modeling plan and the mode choice model requirements, Tables 7.1 and 7.2 present the attributes and levels that have been used for the design of the SP survey.

Respondents were given a prespecified O-D that was chosen based on current traffic volumes and the existence of competitive mode alternatives and then were asked to choose between the following mode alternatives:

**TABLE 7.1** Attributes per mode for freight-stated preference scenarios.

| Per origin and destination | | |
|---|---|---|
| **Heavy vehicles (trucks)** | **Rail** | **Short sea shipping** |
| Travel time | Travel time | Travel time |
| Travel cost | Travel cost | Travel cost |

**TABLE 7.2 Attributes and levels for freight-stated preference scenarios.**

| Attributes | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|---|---|---|---|---|---|
| Travel time (in hours) | −25% of actual travel time | −10% of actual travel time | Actual travel time | +10% of actual travel time | +25% of actual travel time |
| Travel cost (in Euros) | −25% of actual travel cost | −10% of actual travel cost | Actual travel cost | +10% of actual travel cost | +25% of actual travel cost |

road, rail, and SSS. In this chapter, the data collected from these SP scenarios will be used for the development of the freight mode choice model.

## 7.2 Descriptive statistics

The vast majority of the sample in the prespecified routes that were presented as part of the SP survey is currently using road transport modes. More specifically, 61.6% are using four-axle trucks, 16.2% are using five-axle trucks, and 12.1% are using trucks of less than 3.5 tons. The majority of the sample was responsible for the distribution of food, drinks and tobacco, followed by agricultural products (10.1%). Building materials represent 8.7% of the sample, whereas wood and paper products and mine products share the same percentage (7.2%). Almost half of the respondents transfer general cargo/pallets, 28.2% transfer dry cargo, and only 4.2% was carrying containerized cargo.

## 7.3 Freight mode choice model estimation results

This section presents the model specification and estimation results of the freight mode choice models developed for intercity trips within Greece. The final utility for each mode alternative, and subsequently the probabilities of choosing it, is affected by the mode-related attributes, such as travel time and travel cost. The models developed are mixed multinomial logit (McFadden and Train, 2000; and Walker, 2001), capturing (1) correlations among the observations of the same individual and (2) taste variation on the travel time coefficient. For the first two, these correlations are captured through the inclusion of appropriate random error terms, whereas the latter (travel time) is considered to be a random coefficient, independent and normally distributed, imposing the restriction that the coefficient for all members of the population has the same sign and magnitude.

## 7.4 Model estimation results

Table 7.3 presents the estimation results of the model developed. The model was estimated using Python Biogeme (Bierlaire, 2016). The presented model was selected on the basis of statistical goodness-of-fit, (likelihood ratio tests), estimated coefficient significance *t*-tests, and the rho-square ($\rho^2$). The error component is significant, capturing the correlations among the observations of the same individual. Moreover, to verify models identification, a sufficient number of draws have been used to reduce possible bias. More specifically, the model was estimated using various draws (1000, 5000, and 10000) that verified that the parameter estimates are stable. The dependent variable has three alternatives: (1) SSS, (2) rail, and (3) road. The coefficients of travel time and travel cost have the expected signs and are statistically significant at the 90% and 95% confidence level, respectively. As expected, an increase in either travel time or travel cost of an alternative would decrease the probability of choosing it and thus increase the probability of the remaining alternatives.

**TABLE 7.3** Freight mode choice model estimation results.

| Name | Value | *t*-test |
|---|---|---|
| ASC_SSS[a] | 3.63 | 1.54 |
| ASC_Road | 4.40 | 2.45 |
| B_COST_SSS | −0.037 | −2.22 |
| B_COST_Rail | −0.019 | −2.50 |
| B_COST_Road | −0.012 | −2.26 |
| B_TIME_S (standard deviation) | 0.317 | 1.67 |
| B_TIME (mean; generic to all alternative modes) | −0.455 | −1.79 |
| B_TONNETIME_S (standard deviation) | 0.026 | 1.74 |
| B_TONNETIME (specific to rail) | −0.001 | −1.70 |
| Sigma (specific to SSS and rail) | 5.36 | 2.28 |
| Statistics | | |
| Number of observations | 291 | |
| Initial log likelihood | −1370.982 | |
| Final log likelihood | 178.219 | |

SSS, short sea shipping.
[a]*Alternative Specific Constant.*

## 7.5 Analysis of the Value of Time

The model estimation results enabled the calculation of the FVOT in Euros per hour for the three transport modes under consideration. The FVOT is defined as:

$$FVOT_i = \frac{\beta_{TTi\,(mean)}}{\beta_{TCi}} \tag{7.1}$$

where the numerator is the coefficient of travel time (population mean) and the denominator, the travel cost coefficient of the respective mode alternatives. Thus it gives the VoT in Euros per hour. For the rail, we were also able to estimate the value of transport time (in Euros per ton hours), which is defined as follows:

$$VFTT_{rail} = \frac{\beta_{TONETIME\,(mean)}}{\beta_{TCrail}} \tag{7.2}$$

Table 7.3 presents the obtained FVOT per mode, as well as the FVOT in Euros per ton per hour for the rail alternative. The estimated FVOTs do not take into consideration the commodity type transported, container/noncontainer distinction, and/or shipment weight/size variations. Based on the SP design from which the data used for the model developed are derived, the FVOTs concern the same quantity and type of cargo for all modes. The FVOT for road transport in Greece (36 Euros per hour, in 2010 €) is a bit lower in comparison to the FVOTs reported by de Jong et al. (2014) for the Netherlands, where FVOT (depending on the type of shipment) varies from 37 to 59 Euros per hour (in 2010 €). If we compare it with the FVOT estimated by Russo and Chilàa (2007) for Italy, the estimated FVOT for Greece road transport is considerably lower (286 Euros per hour per shipment vs 38 Euros per hour per shipment; in 2017 €). If we can use Italy as a proxy for Greece and use the FVOT estimated in 2007 Russo and Chilàa (2007) as a baseline, the difference observed can be potentially attributed to the financial crisis in Greece and its effect on road transport.

The FVOT obtained for rail transport is lower compared with the FVOT obtained for road transport, and this is consistent with findings from other studies (Zamparine and Reggiani, 2007; Beuthe and Bouffioux, 2008; Russo and Chilà, 2007; Feo-Valero et al., 2011). FVOT estimated for railways and SSS/maritime is difficult to compare with the findings from other studies because of the heterogeneity of the measurements units used [the findings from existing studies vary with respect to time dimension (minutes, hours, and day) and quantity of goods (ton, wagon, pallet, full train, full ship, etc.)]. The estimated FVOT for rail transport (23.6 Euros per hour, in 2017 €) is significantly lower than the FVOT of 68.55 Euros per hour (in 2017 €) estimated by Russo and Chilà (2007). This difference can be attributed to the condition of the rail network in Greece; while if we apply the same rationale

**TABLE 7.4 Freight values of time per mode (Euros per hour per shipment)/(Euros per ton per hour).**

| | FVOT (Euro per hour per shipment) | | |
|---|---|---|---|
| | Minimum | Mean | Maximum |
| Short sea shipping | 3.7 | 12.3 | 20.8 |
| Road transport (truck) | 11.5 | 38 | 64 |
| Railway | 7 | 24 | 40.6 |
| | **VFTT (Euros per ton per hour)** | | |
| Railway | 0.51 | | |

*FVOT*, freight value of time; *VFTT*, freight travel time.

as in road transport, this difference can also be considered partly as a result of the economic recession in Greece. The VFTT estimated for the rail transport, which is 0.51 Euros per ton per hour, is consistent with findings from past studies, based on which VFTT for rail varies from 0.1 to 1.4 Euros per ton per hour (de Jong, 2008).

As far as it concerns the FVOT for maritime transport, the FVOT obtained in this study is considerably lower compared with the findings of García-Menéndez and Feo-Valero (2009) for maritime transport in Spain (26.05 Euros per hour per shipment) and with the findings of Bergantino and Bolis (2008) for maritime transport in Italy (55.65 Euros per hour per shipment). However, if we assume that the reported values from Spain and Italy (both faced a financial crisis at a similar period with Greece) in 2009 and 2008, respectively, can be used as a baseline for FVOT in Greece before the crisis, it could be an indication of the decrease that the authors expected in FVOTs due to the financial crisis. Unfortunately, the authors were not able to identify any previous study for FVOTs in Greece to compare their findings and support their initial assumption Table 7.4.

## 8. Conclusions

This chapter discussed the effects of the financial crisis in Greece on the logistics sector and through a modeling exercise estimated the FVOT for road, rail, and maritime transport modes during the economic recession. To the best of our knowledge, this is one of the first studies conducted in Greece that provides estimates of FVOTs.

A computer-assisted SP survey was conducted in 2017 to 100 freight forwarders. The data collected were used for the development of a mixed multinomial logit model for freight mode choice. The mode choice alternatives considered were road, rail, and maritime transport, whereas the explanatory variables used were the travel time and travel cost of each of the alternatives. Model estimation results revealed that the average FVOTs obtained for all transport modes are lower than the values obtained in countries with similar politicoeconomic conditions, such as Italy, and this partly could be attributed to the financial condition of Greece. However, we should be careful while making such an assumption because there is no previous study that could be used as a reference point for FVOTs in Greece. More specifically, the mean FVOTs derived for road, rail, and SSS are 38, 24, and 12.3 Euros per hour per shipment, respectively. The relative magnitude of the estimated FVOTs suggests that freight forwarders are willing to pay more for road transportation, which is considered to be faster and more flexible, compared with rail and SSS alternatives.

This study had also several limitations that should be taken into consideration. First of all, our sample consists solely of freight forwarders and although there is evidence from the literature supporting this choice, it would be important to enhance it with data acquired from other decision-makers for freight transport, such as shippers. In terms of the survey design, the SP developed was really simplistic and focused on certain routes within Greece. In future research, the SP experiments should be enhanced with additional attributes, such as flexibility, reliability, and commodity type., covering additional routes. The latter will allow also the estimation of more advanced mode choice models, such as latent class choice models and latent variable models. Notwithstanding these limitations, we believe that the findings of our research can provide useful insights to policy makers, transportation experts, and practitioners in emerging economies, where scarcity of available information and funding limitations also exist. The research approach followed was created based on the budgetary constraints and as such can be easily applied in areas where funding is limited and available data scarce.

A future enrichment of the recent freight mode choice model might also take into account the analysis of the sector and logistics developments already planned for the near future. A number of possible issues to be considered in a freight model revision can be cited as follows:

- The dynamics of main gates of the country (Ports of Piraeus and Thessaloniki) might be considered in a way to bring an "intermodal" forecasting approach to the model because the trends of transshipment and modal shift on the sites can be identified separately. Even if the simpler modal representation of "separate" links is retained, additional factors explaining modal shift might bring accurate "corrections" in the model calibration.
- More generally, the analysis of current changes in the role of main ports in the Greek port system might be related to additional factors to the model.

- It is worth examining if it is technically possible to integrate future nodal infrastructure (big logistics platforms) as distinct additional zones within the zonal system of the model platform.
- Freight mode model approaches of VoT might be combined with commodity type approaches because interrelations between inventory costs and modal choice are obvious.

The consideration of the above would allow defining new directions and progressively improve the model. Such a procedure will necessitate additional data collection patterns and survey mechanisms to capture drivers and trends of logistics business, as well as additional attributes to represent changes.

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Chapter 8

# Spatially and commodity-level disaggregated freight demand modeling in emerging economies: Applications for South Africa and India

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## Highlights

- Application of the spatially and commodity-level disaggregated national freight demand models developed in Chapter 4 for South Africa and India.
- The outputs inform data-driven macrologistics policy development and integrated freight-related infrastructure investments including road and rail transport, ports, intermodal terminals and logistics hubs.
- The ultimate goal is to advance the freight sector's contribution to sustainable economies.

## 1. Introduction

In this chapter, the outputs of the disaggregated freight demand models (FDMs) for South Africa and India (methodologically described in Chapter 4) are discussed. As detailed in Chapter, 4, in relation to GDP, freight logistics costs in both South Africa and India are high compared to developed economies. In South Africa this is exacerbated by low economic growth rates, whereas in India infrastructure and service delivery capacity did not keep pace with India's unprecedented growth rates. Both countries also face debilitating

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socioeconomic challenges, including high unemployment and extreme poverty. One of the macrologistics challenges for South Africa is, therefore, to unlock logistics efficiencies and target freight infrastructure investments that will stimulate inclusive economic growth, whereas India is faced with the challenge of creating the required logistics infrastructure capacity both to support current growth trajectories and facilitate broader access to infrastructure. The outputs of the FDMs inform macrologistics policy and investment priorities that are most likely to support the attainment of these goals.

In summary, the methodology detailed in Chapter 4 is a demand-side model, that is, it generates freight flow estimates based on the demand for logistics services required to solve the disparity between place and time utility. This demand is premised on spatial and commodity-level disaggregation of total supply and demand volumes in the economy using hybrid input data, that is, all available actual data on a commodity and district level within the economy in question, and estimating gaps through modeling or proxies. The volumetric supply and demand outputs are then inputs into a gravity model which estimates commodity-level freight flows between the disaggregated origins (supply) and destinations (demand).

This spatial and commodity-level quantification of a country's freight-flow landscape enables:

The identification and sizing of freight flow segments to inform:
data-driven freight policy development;
modal optimization, including the establishment of intermodal solutions and related logistics hubs[1];
the prioritization of large-scale infrastructure investments;
Bottom-up logistics costs modeling as the disaggregated volumetric flows from the FDMs are used as core inputs into logistics and externality costs models[2];

[1] The process of intermodal transport refers to a door-to-door service using various domestic intermodal technologies such as piggybacking, swop bodies, ISO (International Organization for Standardization) containers and nonstandard solution-specific containers. Short-distance feeder services of these laden intermodal technologies to an intermodal terminal at a logistics hub are provided by road. Laden intermodal technologies are consolidated on flat rail cars to create main-line block trains running the length of the corridor to a destination terminal, where it is transported to distribution centers or end destinations via road transport. In the case of domestic intermodal solutions in South Africa, the relevant transport modes are road and rail freight transport (South Africa has no inland waterways). In the case of India, road, rail, and inland waterways will be included in the planning of intermodal solutions.

[2] The first disaggregated national FDM and transport cost component of the logistics costs model for India was developed in 2016−17. The calculation of total national logistics costs for India, that is, including storage and port handling costs, management and administration costs, and inventory carrying costs, as well as externality costs are on the research agenda. The full logistics and externality costs models have been developed for South Africa. (Refer to Havenga and Simpson, 2014, and Havenga, 2015, for the methodologies, and for South Africa's full set of results.)

Macrologistics applications such as modeling the impact of externality cost internalization and identifying priority areas for improving the competitiveness of international trade supply chains[3].

This chapter is structured as follows. For each country, a description of the macrologistics status quo and transport market segmentation is provided upfront to highlight the country's major freight logistics challenges. For South Africa, the FDM™ outputs are then analysed to present the modal shift opportunity for the country's intermodal business case; the utilisation of the outputs to inform rail and port investments is described; and the priority area for reducing international trade logistics costs is identified. For India, the FDM outputs are utilised to highlight challenges and opportunities on the country's Eastern Corridor as part of the dedicated freight corridor investment project. The chapter concludes with a discussion on model validation and next steps in this regard.

## 2. South Africa

### 2.1 Macrologistics — an understanding of the national freight flow landscape

South Africa's surface freight transport volumes (i.e., road and rail) amounted to 850 million tons in 2017. The primary economy (i.e., the agricultural and mining sectors) contributed 76% of these volumes while only contributing 45% to the transportable GDP (i.e., in value terms). In contrast, the secondary economy (i.e., the manufacturing sector) contributed the remaining 24% of surface freight transport volumes, while amounting to 55% of the transportable GDP.

Maps of the aggregated freight movements for the agriculture, mining, and manufacturing sectors are shown in Fig. 8.1. Agricultural freight volumes are low compared with the other sectors (in line with its GDP contribution — 2% of total GDP and 11% of transportable GDP). Mining dominates, consisting mostly of the dedicated rail-only export lines of coal (through the Port of Richards Bay) and iron ore (through the Port of Saldanha). Manufacturing commodity flows are highly densified along the country's two key general freight corridors, namely, Gauteng−Cape Town (over an average transport distance [ATD] of 1400 km) and Gauteng−Durban (over an ATD of 550 km). These two corridors carry 8% of all freight tons transported in South Africa, and 34% of corridor tons. The geographical representation also highlights the marginal participation of rural areas in the national economy (as indicated by the low density of noncorridor freight flows).

[3]These calculations are only presented for South Africa (refer Footnote 2).

The overarching freight flows depicted in Fig. 8.1 point to a threefold freight flow optimization focus within the South African economy: (1) in terms of **volume** to continue leveraging the country's natural endowment of and infrastructure investments in bulk mining exports, (2) in terms of **value** to increase the competitiveness of current domestic and export flows and to enable further local beneficiation opportunities to stimulate inclusive economic growth and employment, and (3) in terms of **access** to increase the participation of the rural economy, with a priority area the revitalization of branch lines (for the latter, refer to a study by Simpson and Havenga, 2010).

The 850 million tons of surface freight transport volumes mentioned earlier resulted in a demand of 371 billion ton-km in 2017. This ton-km demand within the South African economy is disproportionate to the size of the economy. Globally, about 32 trillion surface freight ton-km (i.e., road and rail) are required (International Transport Forum, 2017) to

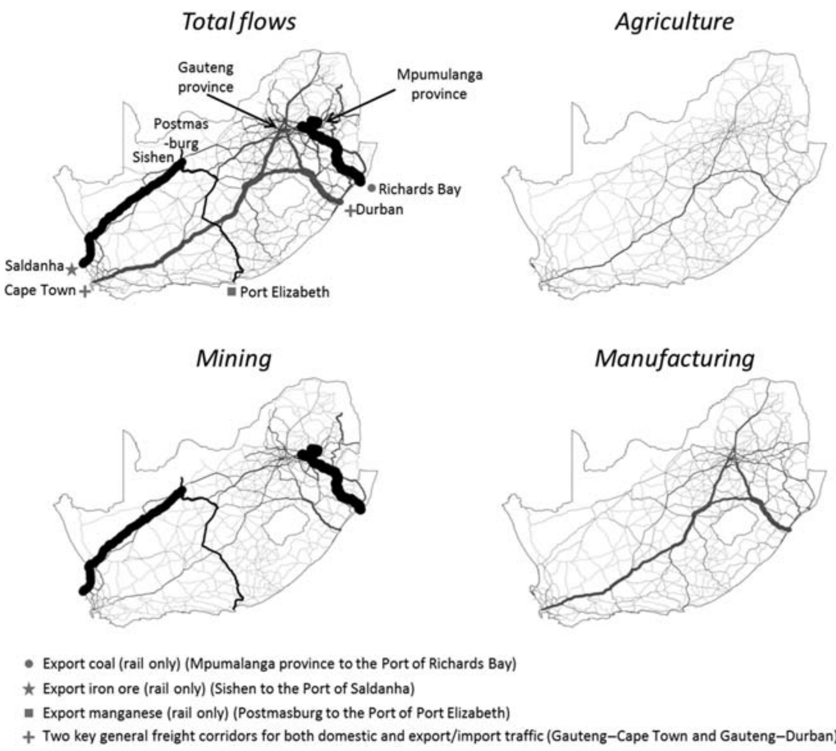


**FIGURE 8.1** South Africa's aggregate and sectoral freight flows in 2017 (created by authors).

generate $75 trillion of GDP (World Bank, 2017), that is, approximately $2.4 return for every ton-km provided by logistics service providers. The South African GDP amounts to $317 billion (World Bank, 2017) for the 371 billion surface freight ton-km provided, that is, the country's return is less than $1 for every ton-km provided. The country's ton-km demand is, therefore, almost three times less competitive than the world average, an extraordinary backlog from the outset.

From an economic structure point of view, one of the reasons for this is that South Africa is a spatially challenged country, that is, a relatively small economy in relation to a large landmass, with mining deposits and resulting surrounding developments located far from ports and coastal demand areas. The country also has a historical reliance on bulk exports, increasing the pressure on logistics infrastructure at low returns. This talks to the need for increased beneficiation.

From a transport provision point of view, the country's modal structure is a key contributing factor. The country's dedicated ring-fenced transport systems (i.e., the rail export lines, pipelines, and conveyor belts) contributed 28% of total surface freight ton-km in 2017. The remaining 267 billion ton-km (or 72% of total flows) is categorized as general freight. General freight can be further disaggregated into three typologies: (1) freight that flows on long-distance corridors (i.e., between major metropolitan areas such as Gauteng–Durban and Gauteng–Cape Town), (2) freight that flows within metropolitan areas, and (3) freight that flows to, from, and within rural areas, as delineated in Fig. 8.2. Approximately half of the general freight is long-distance corridor freight, with road freight transport contributing 84% of corridor ton-km.

Historically, road increasingly served the growing economy because of rail's investment backlog, with social accountability preventing rail rationalization, resulting in an inability to provide the service levels required by a changing economy. Road freight transport's dominant long-distance market share comes at the expense of high national logistics and externality costs, with road freight transport costs constituting 80% of total national transport costs and externalities adding an additional 24% to already high transport costs; the contribution of nonroad modes to these externality costs is negligible (2017 data, for methodology, refer to Havenga, 2015).

A macrologistics strategy and infrastructure investment response to address these challenges should unfold no different from business-level market strategy development and subsequent investments. The latter is based on (1) understanding total market demand, (2) segmenting this demand according to market requirements (including customer needs, product characteristics, and service preferences), (3) deciding in which market segments the business will compete based on the business' core

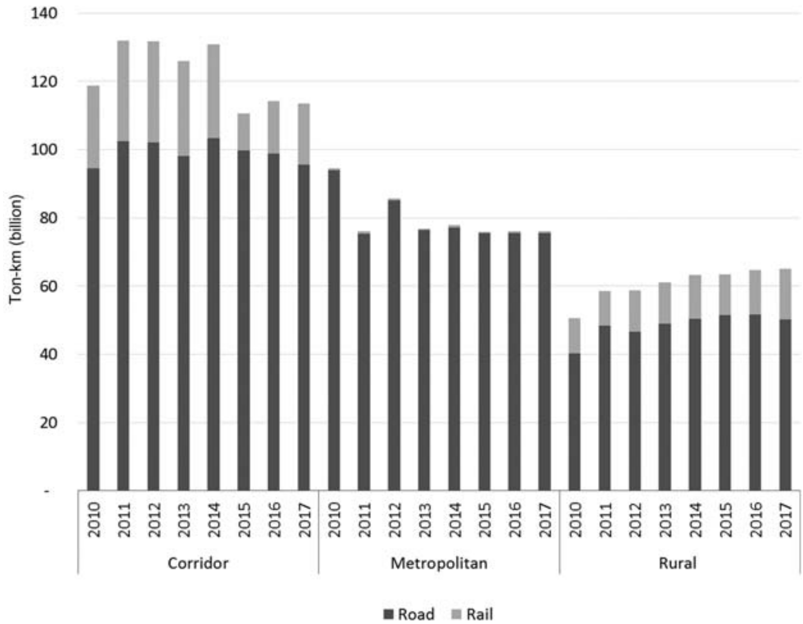


**FIGURE 8.2** Typological division of South Africa's general freight transport (created by authors) (for rail, general freight excludes the rail-only exports of coal, iron ore, and manganese).

competencies, and (4) investing and resourcing for service delivery against this market strategy.

Akin to this market strategy development process on a business level, the foundation of a sustainable freight transport industry is an understanding of the unique freight market segments, as informed by market requirements. This process should unfold as follows: (1) total market demand refers to an understanding of all freight flows in the country, (2) segmentation is the classification of these freight flows into specific market segments based on market requirements, (3) the competitive market space is informed by the matching of different transport modes' core competencies with market requirements to (4) inform long-term infrastructure master planning and freight transport policy development. These planning phases should focus on investing for the optimal modal split for a country based on its freight profile (not limited to current modal challenges) to address socioeconomic disparities, reduce freight transport externalities, and facilitate future mobility amidst ever-increasing freight movements. (The question of demand reduction to reduce freight transport — as a sustainability measure — falls outside the scope of this chapter but is important to note for scenario development and planning purposes. Refer *inter alia*

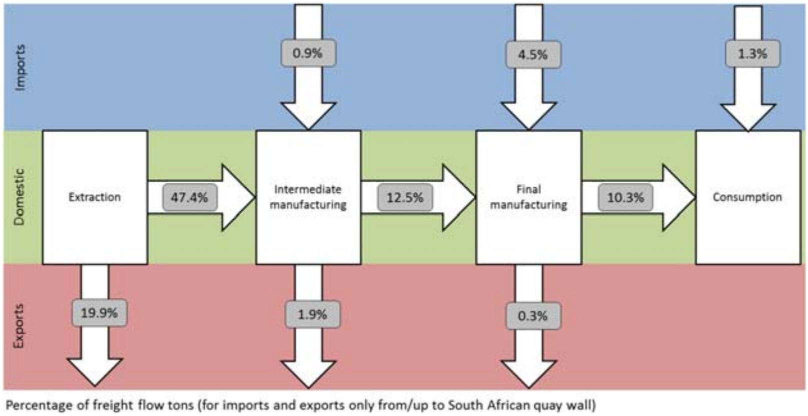


**FIGURE 8.3** Freight flows tons in South Africa depicted in terms of the economy's basic value chain (2017; created by authors).

Meadows et al. (1972); Demaria et al. (2013), and Kallis (2017) for further reading).

The next section describes the transport market segmentation outputs for South Africa.

## 2.2 Transport market segmentation

As defined in Fig. 4.5 and Fig. 4.6 in Chapter 4, and illustrated in Fig. 8.3, freight flow segments are derived from the economy's basic value chain and its related logistics requirements. Freight flows take place from the place of extraction or manufacture to the place of utilization or consumption (including import and export flows), resulting in key flow patterns.

These flow patterns give rise to five overarching freight flow segments, with subsegments, as dictated by the nature of the commodity and service requirements (refer Table 4.3 in Chapter 4 for segment descriptions and Fig. 8.4 for flow outputs).

To inform decision-making, these transport market subsegments can be further depicted in terms of core freight transport characteristics, namely, transport distance, cost, and density (Harris, 1977; Van der Meulen, 2007), as illustrated for general freight in Fig. 8.5[4] (density is defined as the volume of traffic per kilometer of railroad, expressed as ton-km per route-km).

The above transport market segmentation analyses confirm the threefold focus in freight flow optimization required within the South African economy described in Section 3.1. The **volume** focus requirement is evident from

[4] Fig. 8.5 excludes the bulk exports of coal, iron ore, and manganese because of scale issues and the rail-only nature of these flows.

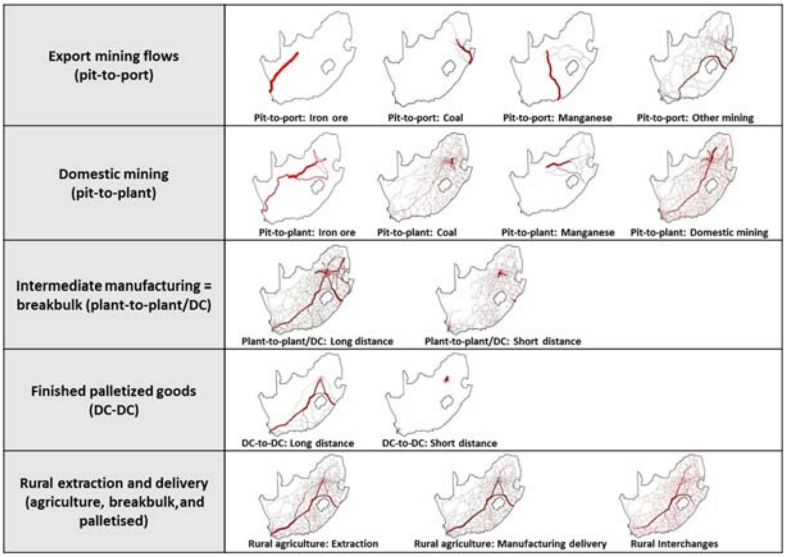


**FIGURE 8.4** South Africa's transport market segments and subsegments (excluding pipelines, conveyor belts, and metropolitan traffic; flow lines not same scale; Havenga, 2012; refer Fig. 8.1 for a map of South Africa indicating the main locations).

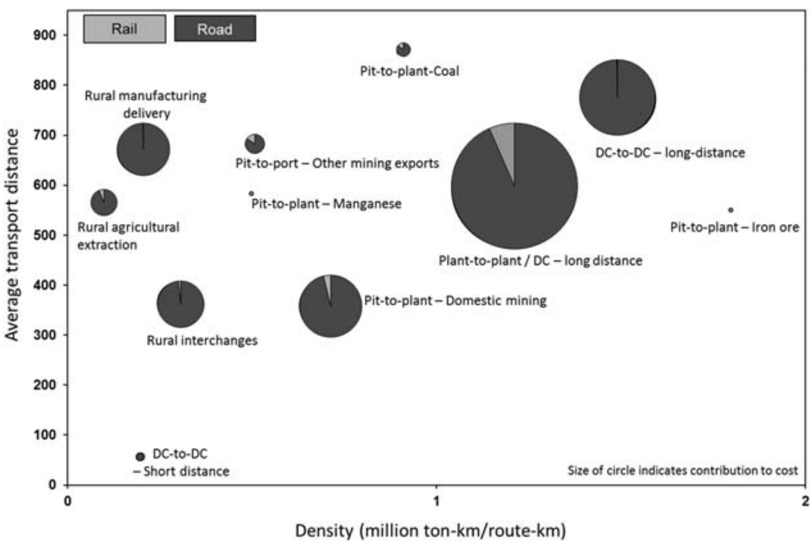


**FIGURE 8.5** South Africa's general freight transport market segment positioning (Havenga, 2012).

the dominance of tons in the extraction sector (Fig. 8.3), the **value** focus from the dense long-distance intermediate and final consumption flows (Fig. 8.5), and the **access** focus from the low density, relatively high-cost rural flows (Fig. 8.5). (Underpinning these aggregate depictions is the detailed spatial and commodity-level disaggregation, described in Table 4.2 in Chapter 4).

Rail-friendly traffic is defined as high-density flows between distribution centers (DC-to-DC), and plant-to-plant/plant-to-DC flows over long distances. Rail's low market share in rail-friendly traffic on road is evident (Fig. 8.5). The aggregated volumes of rail-friendly traffic on road indicate that 15% (or 64 million tons) of the tonnage on road, and 21% (or 32 billion ton-km) of the transport task on road can be served through an intermodal solution. This is a high-impact intervention to reduce the transport costs of the identified rail-friendly segments, as discussed in the next section.

## 2.3 Modal shift

Intermodal[5] solutions provide a door-to-door freight transport service leveraging the strength of different transport modes (refer footnote 1). Road provides feeder services to an intermodal hub, thereby providing reach, flexibility and just-in-time services. Rail or waterways consolidate intermodal freight for long-distance transport, which reduces logistics and externality costs (Yevdokimov, 2000; European Commission, 2008) since intermodal consolidation leverages key rail economic principles of freight uniformity, terminal density and long-distance line density (Van Eeden and Havenga, 2010; Simpson, 2013).

The key steps for identifying intermodal-friendly freight are as follows (Van Eeden and Havenga, 2010; Havenga et al., 2012):

- Develop a detailed view of all freight flows in an economy (such as through the development of a disaggregated national FDM described in Chapter 4) (refer Sections 3.1 and 3.2 above for the outputs for South Africa);
- Segment the freight flow outputs to enable the identification of freight flows with similar transport and logistics needs. This is an iterative approach informed by *inter alia* commodity type, geographical location, transport distances, and load densities, with an output that can be depicted as in Fig. 8.6.
- Utilize the segmentation outputs to identify intermodal-friendly freight with the key characteristics of high density, long distances, and palletizability (the latter to facilitate stacking for transport in containers) (Woodburn, 2008). The rationale for this approach is that corridor or

[5]This section is based on a study by Havenga et al. (2012).

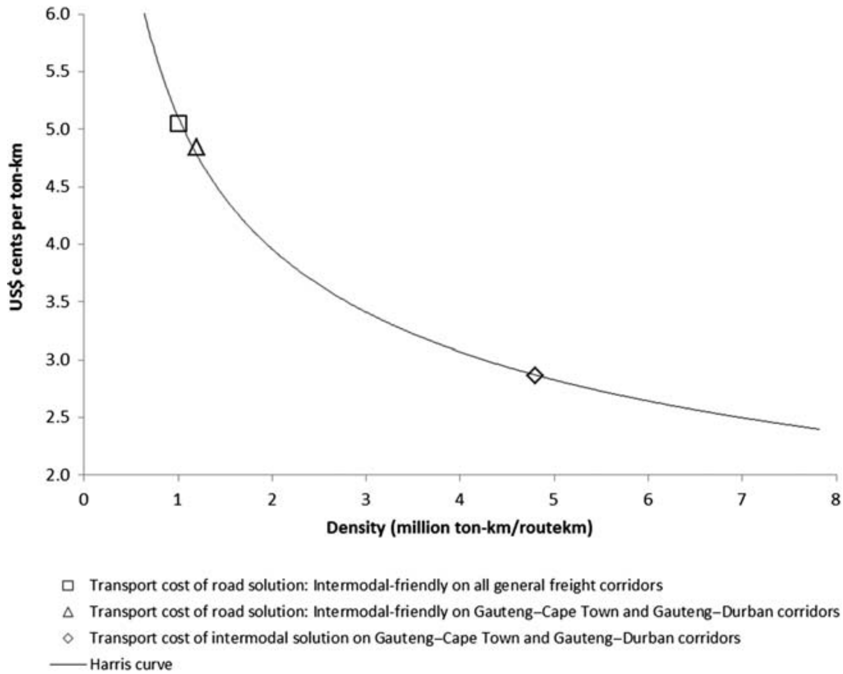


**FIGURE 8.6** Potential cost savings on South Africa's two most-dense general freight corridors because of density improvements resulting from a modal shift (Havenga et al., 2012).

long-haul traffic can be transformed to fewer long-distance origin-destination (O-D) pairs if the collection and distribution can be performed efficiently from a central hub at both ends of the long-distance corridor through the implementation of intermodal solutions. The corridor then becomes a combination of dense, long-haul (end-to-end) traffic, which leverages the key rail economic principles (freight uniformity, terminal density and long-distance line density, as mentioned earlier), and short-distance distribution (metropolitan), which leverages the core competencies of road transport. 'Long distances' is a unique characteristic of each country[6]. In South Africa, the majority of palletizable commodities are transported over distances greater than 500 km.

The outputs of this analysis indicated that more than half of South Africa's potential intermodal freight moves on the country's two most dense

[6] Examples of country-level average transport distances: the United States Class 1 Railroads = 1642 km in 2016 (Bureau of Transportation Statistics, 2018); the United States "dry van" truckloads = 840 km in 2017 (American Transportation Research Institute, 2019); Europe top three economies by GDP (Germany, the United Kingdom, and France): rail freight 312 km in 2016 (Eurostat, 2019a) and road freight: 99 km in 2016 (Eurostat, 2019b).

freight corridors, that is, Gauteng to Durban, and Gauteng to Cape Town (refer Fig. 8.1 for density indication). Building three intermodal terminals to connect the three major industrial hubs — Gauteng, Durban, and Cape Town — and implementing an intermodal solution on the two corridors will enable modal shift to rail due to cost reductions attributable to increased rail densities. The analysis indicated that this could reduce logistics costs (including externalities) for the identified intermodal freight flows on these two corridors by two-thirds (Havenga et al., 2012). The potential cost reduction achieved through an intermodal solution is driven by a shift on the Harris (1977) curve[7] because of an increase in density (refer Fig. 8.6).

Havenga and Simpson (2018) postulated that such a shift of rail-friendly traffic on road to rail (serviced through intermodal solutions) can be induced through internalizing externality costs. Their analysis indicated that the full cost in a road-to-rail shift scenario (i.e., including internalized externality costs) is lower than the internal costs before internalization. The negative (external) effects of transport in South Africa can, therefore, be negated without incurring additional costs on the macroeconomic freight bill because of the returns to density achieved by shifting rail-friendly freight back to rail.

## 2.4 Large-scale infrastructure investment planning

South Africa's disaggregated national FDM™ provides the medium- and long-term (30-year) freight transport demand forecast used as input into Transnet's (the state-owned port, freight rail, and pipeline operator) long-term planning framework (Transnet, 2017). South Africa's FDM™ volume outputs (volumes on O-D level per commodity, which can be aggregated according to typologies (refer Section 3.1) or predefined geographical or industry groupings) are translated into a transportation plan that, at the outset, models **all** flows over the rail network for planning purposes. Based on commodity, density, and distance characteristics, road-friendly, rail-friendly, and contestable flows are then defined. Finally, a medium- and long-term rail addressable market (RAM) is deduced from these flows. The medium-term RAM is used to engage with business managers to agree on a ratified target for each business segment. The capacity to execute this target is then planned for on a line segment basis for infrastructure planning, as well as on an operational level for equipment and processes. The long-term RAM is used for long-term investment planning. For ports, a similar process is followed but instead of line capacity, required port and terminal capacity are

7The positive relationship between cost reduction and improvement in density was first demonstrated by Harris (1977). The potential cost savings experienced on rail because of the introduction of an intermodal solution can be attributed to a more favorable relationship between fixed and variable costs where more freight is available to absorb rail's high fixed costs.

informed by volume forecasts from South Africa's FDM™. The outputs are also used in Transnet's shareholder compact (with government, its only shareholder) for target setting based on Transnet's contribution to the economy. Finally, the outputs enable scenario analyses, which inform a positioning platform to deduce Transnet's inputs and response to the regulatory and policy debate in South Africa.

The comprehensive platform provided by South Africa's FDM™ ensures that short-term decisions take cognisance of the national freight flow environment and the potential long-term repercussions of investment and market development decisions. It also provides the government with data-driven projections which may, in turn, inform and support national development strategies and policies taking cognisance of the national freight flow landscape.

## 2.5 Reducing international trade logistics costs in South Africa

In South Africa[8], user concerns regarding port costs and efficiencies, compounded by the ownership of South African ports and the national railway by a single entity (Transnet), led to the accounting separation of the landlord and terminal operator tasks in 2002, under the auspices of Transnet Port Authority and Transnet Port Terminals, respectively, followed by the establishment of the Ports Regulator of South Africa in 2007. Concerns regarding the impact of port efficiencies on international trade competitiveness, however, remain and frequently lead to calls for more reform (Havenga et al., 2017).

A research project was launched with the objectives to identify and quantify the components of international trade logistics costs (ITLCs) and, through this quantification, to assist port stakeholders in prioritizing interventions that will have the biggest impact on enhancing trade competitiveness. For the purposes of this research, ITLCs were defined as the inland logistics costs of imports and exports (obtained from South Africa's logistics costs model), port authority charges (vessel charges and cargo dues), handling charges at port terminals, maritime transport costs, ship standing costs, truck standing costs, documentation charges, and inventory carrying costs because of freight delays in the port (refer Havenga et al. (2017) for the detailed methodology).

The country's total ITLCs (up to and from foreign port gates) amounted to US$22.3 billion or 11.7% of trade GDP in 2014 (i.e., the value of all traded commodities, amounting to US$190 billion) (refer Fig. 8.7). As a direct result of South Africa's spatial challenges, with centers of production and consumption far from ports, the highest portion of these costs is inland logistics costs, amounting to 41.8% (US$9.3 billion) of ITLC. Given South

[8]This section is based on a study by Havenga et al. (2017)

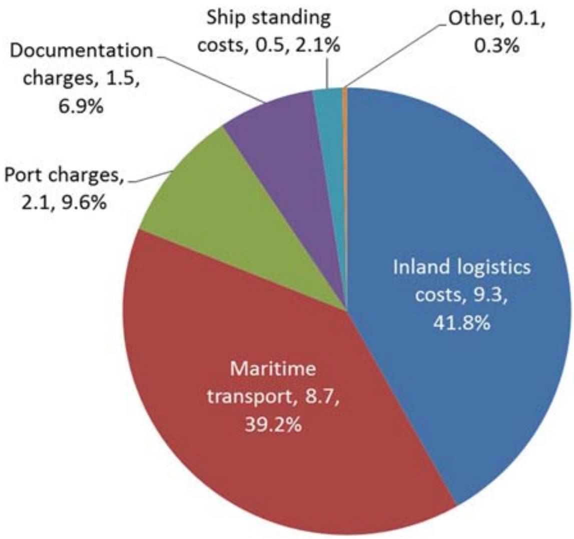


**FIGURE 8.7** International trade logistics costs for South Africa (US$bn, 2014; Havenga et al., 2017).

Africa's distance from global markets, ocean carrier costs are also very high, at 39.2% (US$8.7 billion).

Approximately half of the remaining 20% is paid directly to ports in port authority and port terminal charges, whereas the remainder is referred to as induced costs for trade-related documentation and additional transport costs because of the delay of ships in front of and in the port.

Induced costs (i.e., documentation charges and ship standing costs) are, therefore, more or less equal to direct port charges. A reduction in induced costs requires more streamlined documentation processes (i.e., improving the ease of doing business) and faster turnaround times (better port productivity, improved scheduling from truckers and shipping lines, and better coordination between ports and logistics service providers). These objectives can be achieved within the current governance framework.

Domestic logistics costs are, however, still by far the biggest cost contributor and can be reduced through modal shift (as discussed in the previous section), more efficient road transport, and spatial strategies. This will have a bigger impact on ITLC than an attempt to reduce port costs through more reform. Spatial strategies can be realized over the medium to long term and include an equitable development of infrastructure across South Africa's geography [the focus of the country's 18 strategic infrastructure projects (Presidential Infrastructure Coordinating Commission, 2012) and the Industrial Policy Action Plan, which promotes investment in the productive sectors of the economy (Department of Trade and Industry, 2016)], which could change freight flow patterns over time. Modal shift is, however, within the short to medium reach of the economy, given sufficient political will. One scenario to enable this is the internalization of externality costs (refer to Section 3.3). The latter will also improve road transport efficiencies, in conjunction with other initiatives.

The results, therefore, suggest that collaboratively confronting port congestion and the hinterland feeder system could unlock much more value for port stakeholders in the short to medium-term than pursuing further port reform in isolation.

## 3. India

### 3.1 Macrologistics — an understanding of the national freight flow landscape

Total surface[9] freight transport flows (road and rail) in the Indian economy amounted to 4.6 billion tons in 2015. The primary sectors of the economy (agriculture and mining) were responsible for 61% of this volume while contributing 54% to the transportable GDP (i.e., in value terms). The secondary (manufacturing) sector contributed the remaining 39% of volume while adding 46% value to the transportable economy. These volumes translated into 3.1 trillion ton-km at a transport cost of US$130.0 billion. Rail's market share of tons transported was 21.7%.

Similar to South Africa (discussed in Section 3.1), India's ton-km requirements in terms of GDP are inefficient. The Indian GDP amounted to $2.1 trillion in 2015 (World Bank, 2017), requiring 3.1 trillion surface freight ton-km, that is, the country's return amounted to $0.7 GDP for every ton-km provided (compared with the global figure of $2.4 mentioned in Section 3.1).

The supply and demand volumes that give rise to these aggregates are illustrated in Fig. 8.8 below. The high density on the central east and west coasts, with pockets of density throughout the country, provides a challenge to cost-effective transport solutions.

The interaction between the supply of and demand for goods on a district level gives rise to the flow of freight in the economy, as depicted in Fig. 8.9. This highlights the dense, quadrilateral concentration of freight flows, creating the so-called Golden Quadrilateral connecting the four major metropolitan areas New Delhi, Mumbai, Chennai, and Kolkata, a distinct feature of India's transport landscape. The highest density is evident on the Eastern Corridor (1500 km by road between New Delhi and Kolkata).

Seventy percent of India's transport task in ton-km is delivered by road freight transport, with rail responsible for the remainder, equating to one-fourth of freight tonnage shipped, while earning only one-sixth of the

[9]This section is based on a study by Aritua et al. (2018)

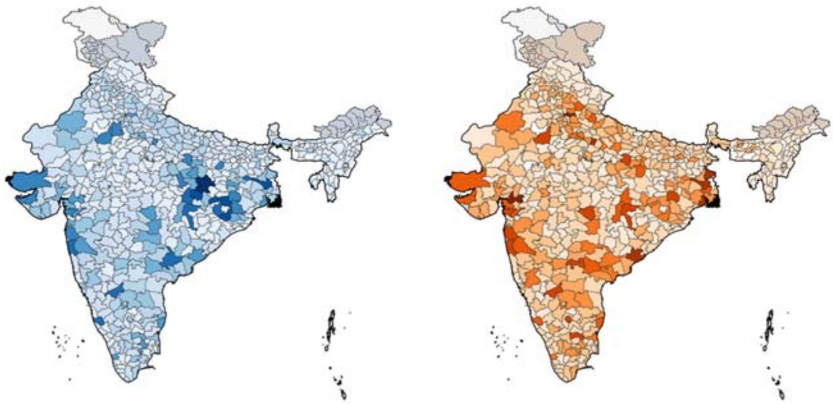

**FIGURE 8.8** Total supply (left) and demand (right) in India for all commodities (tons 2015) (created by authors — darker shades = higher density). (Refer Fig. 4.3 in Chapter 4 for a depiction of the disputed borders between India, China, and Pakistan.)

transport cost in the economy. India's vast geographical size gives rise to significant long-distance transport activity. The ATD on road is almost 500 km, which is significantly higher than the 300 km from which intermodal traffic is regarded as feasible (Kallas, 2011; Sanchez-Triana et al., 2013). There, therefore, seems to be a sizeble opportunity for modal shift.

While a quarter of the freight tons transported use India's major freight corridors, 56% of the transport task in ton-km are on corridors (refer Table 8.1). Reducing the ever-increasing congestion as well as direct and externality costs of freight transport on these corridors is, therefore, a primary priority. Rail is better suited to dense long-haul freight flows, as it is more cost-efficient while also eliminating the externalities of road transport such as emissions, congestion, and the rate of wear on highways (Slack, 2016; also refer South African example in Section 3.3).

As in many other emerging economies, there are three primary factors, which reinforce the choice of road above rail and, in the case of India, waterways. These factors relate to the (current) greater operational efficiencies of road transport, insufficient rail and waterway infrastructure, and the lack of integration between modes, which hamper the door-to-door solutions offered by road transport in isolation (albeit at higher direct and externality costs). Although both rail and waterways offer lower transport costs per ton-km (refer Fig. 8.10), the total supply chain cost may be higher when using rail if the user has to account for longer lead times and (current) unreliability. In addition, the incorporation of rail transport into an end-to-end supply chain solution requires the capability to switch freight at efficient intermodal terminals to a reliable rail service (both of which currently do not exist in India) to mitigate the additional handling costs and longer lead times.

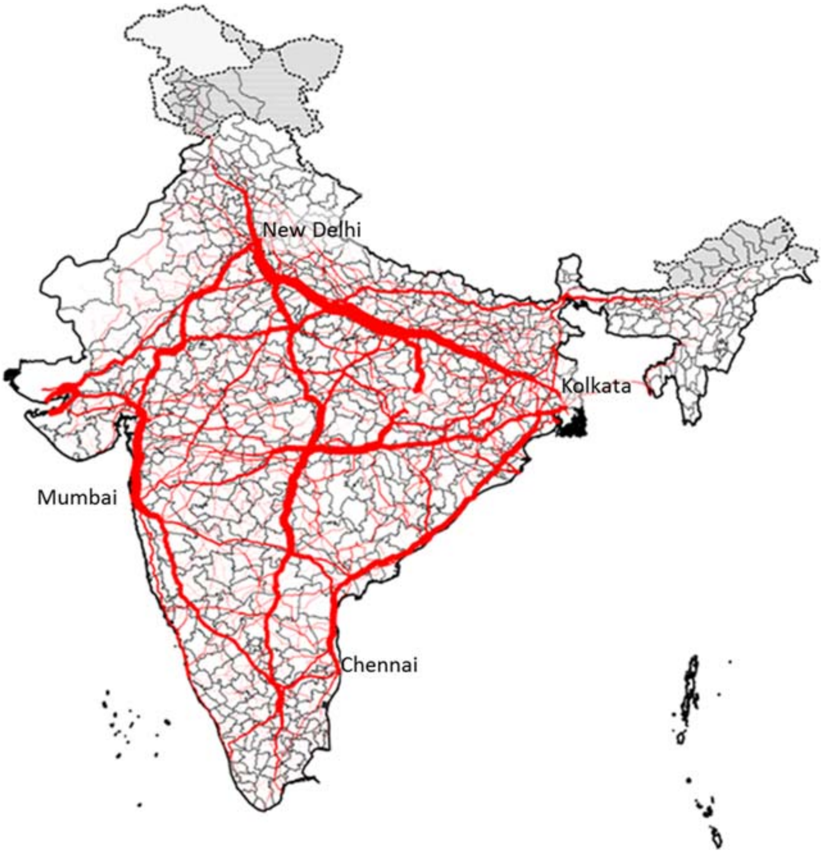


**FIGURE 8.9** Total freight flows in India (2015 data; Simpson et al., 2016). (Refer Fig. 4.3 in Chapter 4 for a depiction of the disputed areas between India, China, and Pakistan.)

**TABLE 8.1 Freight flows in India — typological segmentation (2015 data, excluding urban and waterways; Aritua et al., 2018).**

| Mode | Tons | | Ton-km | | Average transport distance |
|---|---|---|---|---|---|
| | Millions | % | Billions | % | |
| Corridors | 1207 | 26 | 1712 | 56 | 1419 |
| Other freight flows | 3440 | 74 | 1366 | 44 | 397 |
| Total | 4647 | | 3078 | | 662 |

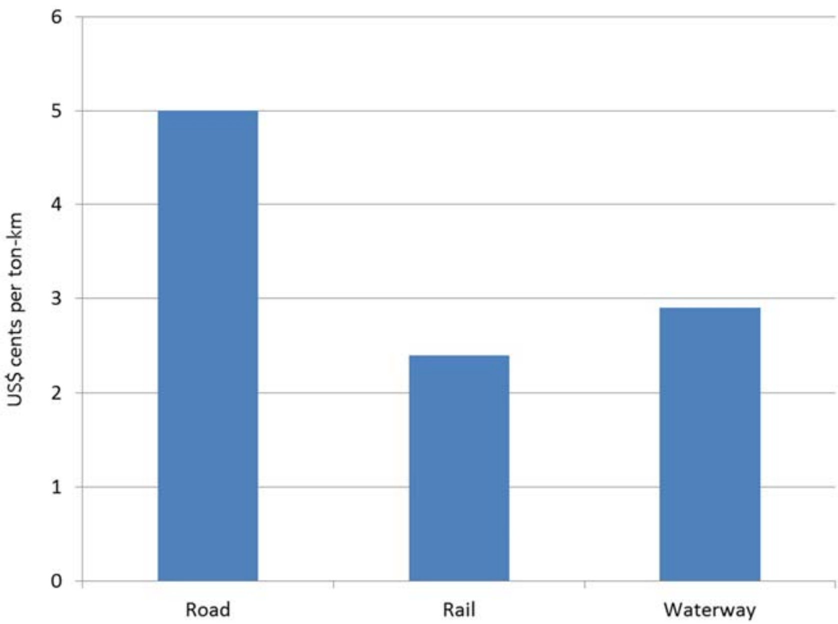


**FIGURE 8.10** Rate comparisons for inland modes in India (national average rates per mode for 2015; Aritua et al., 2018).

As expected, given road's dominant market share, fuel is the major road transport cost driver, contributing 51% of the overall road transport costs (Fig. 8.11). Fuel inefficiencies attributable to an aging and undermaintained vehicle fleet, exacerbated by poor road conditions and severe congestion, also inflate fuel costs. The poor road conditions also wear tires quicker, adversely influencing this second-largest road cost element. The minimal cost contribution of maintenance and repair, and insurance, is concerning, as it confirms the assessment by Kumar (2014) that the fragmented and informal nature of the trucking industry results in many operators who "drive under the radar" with unroadworthy, uninsured vehicles that are most likely also overloaded and unlicensed causing further damage to infrastructure. Apart from normalizing the road-rail modal split, improved road transport efficiency is high on the agenda.

## 3.2 Transport market segmentation

As defined in Table 4.3 in Chapter 4, freight flow segments are derived from the economy's basic value chain and its related logistics requirements, as illustrated for India in Fig. 8.12.

These flows can also be summarized according to cargo type, which clearly highlights rail's low market share in the high-volume, dry bulk and

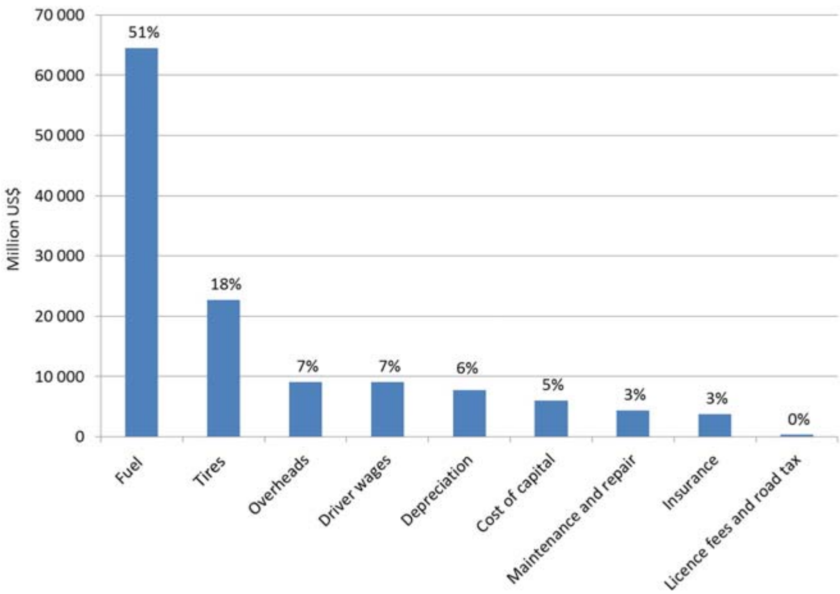


**FIGURE 8.11** Road freight transport's cost drivers in India (data for 2015; Aritua et al., 2018).

heavy break bulk freight that should be the core competence of freight rail services (refer Fig. 8.13).

Two core reasons for the poor performance of freight rail are the investment backlog and the high priority given to passenger transport. Over the past six decades, rail freight tons in India have grown by 1344% and passenger kilometers traveled by 1642%, whereas railway capacity, measured in route-kilometers, has grown by only 23% (PhillipCapital, 2016). The major rail lines, linking the four metropolitan cities of Delhi, Mumbai, Chennai, and Kolkata and its two diagonals (Delhi–Chennai and Mumbai–Howrah), account for 16% of total route length while carrying more than 52% of the passenger traffic and 58% of revenue earning freight traffic of the Indian Railways. The existing trunk routes of Howrah–Delhi on the Eastern Corridor and Mumbai–Delhi on the Western Corridor are highly saturated, with line capacity utilization varying between 115% and 150% (National Transport Policy Development Committee, 2014). The lack of investment in and high saturation levels of rail are compounded by capacity conflicts (refer Fig. 8.14), with the majority of rail capacity allocated to passengers (as reflected in freight vs passenger ton-km per capita — compared with China, Russia, and the United States), also evidenced by the cross-subsidization of passenger services by freight services, where the income from passenger services has been consistently below cost since the turn of the century (the period for which data was made available), compared with freight cost recovery of 1.3–1.6 times freight costs.

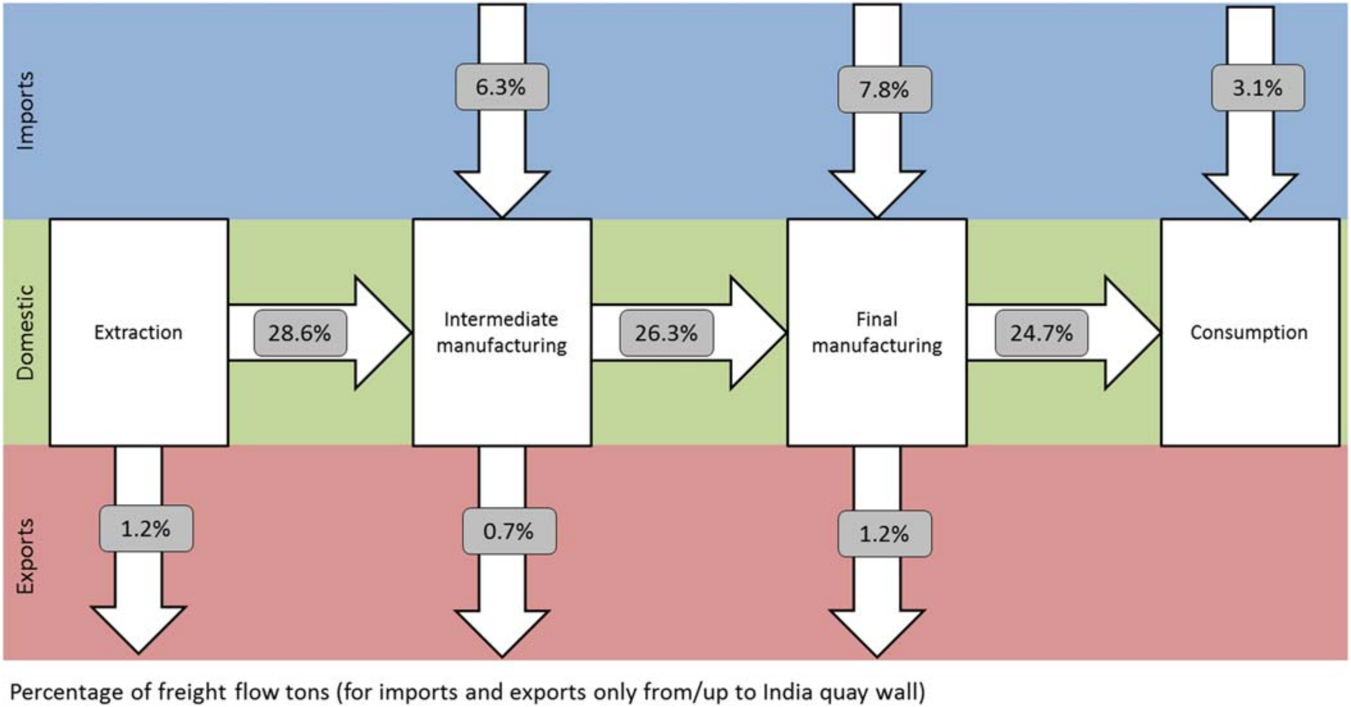


**FIGURE 8.12** Freight flow tons in India depicted in terms of the economy's basic value chain (data for 2015; created by authors).

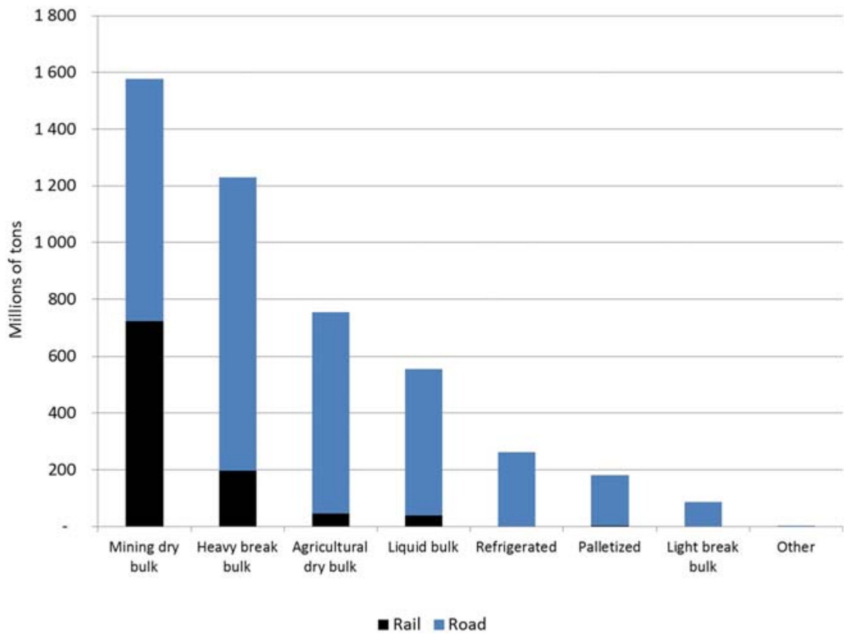


**FIGURE 8.13** India—Modal market share per cargo type (2015).[10]

To address these challenges, the Indian Railways committed to an exponential investment increase in the next 5 years (refer to Fig. 8.15). Six dedicated freight corridors (DFCs) are planned in a phased manner, of which the Eastern and Western Corridors have been prioritized. The phasing of corridors is synchronized with the most saturated sections on the Mumbai-Delhi and Delhi-Kolkata rail links (PhillipCapital, 2016). The vision is that the DFCs will be used exclusively for freight trains, leaving the existing lines free for passenger trains (Makwana, 2016). Improved performance on these DFCs will be supported by high-speed rail and double-stacking which will, in turn, reducing investment requirements in wagons and increasing turn-around times (Kumar and Shah, 2016; Makwana, 2016).

To[11] support the business case for these investments, the disaggregated national FDM was interrogated using the Eastern Corridor, the most dense corridor (refer Fig. 8.9), as a case study.

[10] Currently, inland waterway transport (IWT) in India is negligible, despite India's extensive IWT network and the cost-efficiency of IWT. Investing for growth in IWT is on the agenda. Although not included in this chapter, India's disaggregated national FDM will play an important role in identifying and investing for IWT potential.

[11] Source data in Indian rupee, conversion to US$ based on exchange rates from the Organization for Economic Co-operation and Development and International Monetary Fund.

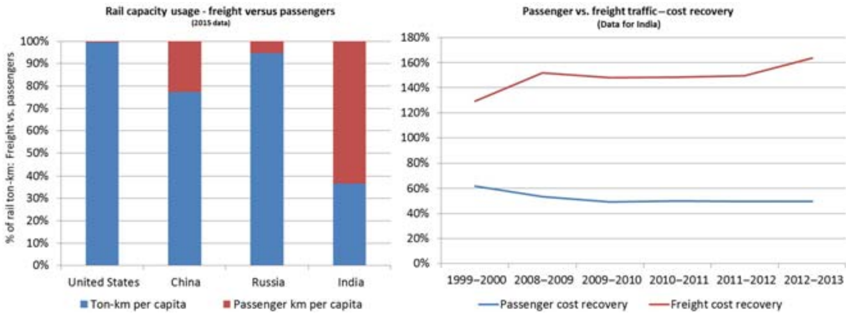


**FIGURE 8.14** Rail capacity and cost recovery challenges in India (Aritua et al., 2018).

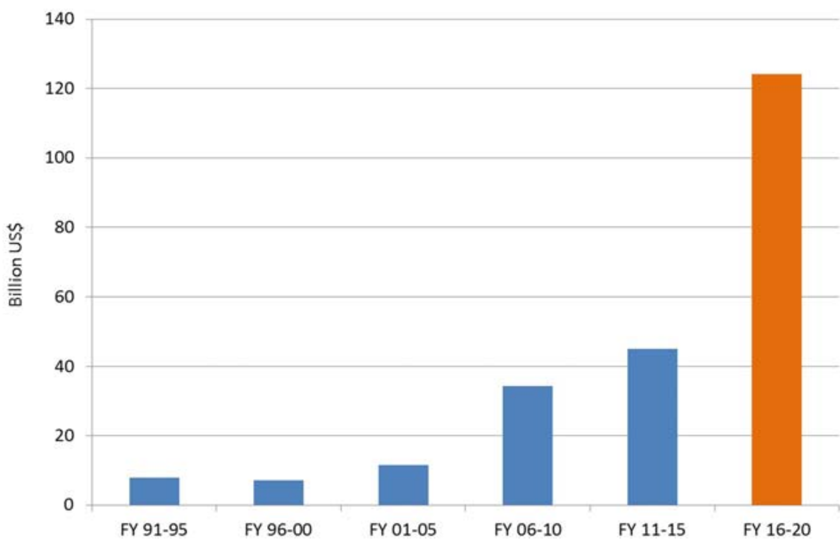


**FIGURE 8.15** Exponential increase in investments by the Indian Railways (Kumar and Shah, 2016).

## 3.3 India's Eastern Corridor

India's Eastern Corridor was identified as a priority focus for India's DFC network. One-fifth of India's total corridor ton-km and one-fourth of total corridor tons are transported on this corridor. In the context of India's national freight flow picture, this represents 6% of freight tonnage, 10% of freight transport activity, and 8% of freight transport costs. Seventy percent of this freight is on road. In contrast to aggregated national freight flows, the rail market share of tons transported and the transport task (ton-km) is almost equal, indicating long road transport distances and a relatively undeveloped rail sector, also illustrated by a relatively low cost market share, that is, mainly low-value commodities are transported on rail (refer Table 8.2).

**TABLE 8.2** Road and rail freight on India's Eastern Corridor (2015 data: Aritua et al., 2018).

| Mode | Tons | | Ton-km | | Average distance | Transport cost | |
|---|---|---|---|---|---|---|---|
| | Millions | % | Billions | % | | US$ billion | % |
| **Road** | 206.6 | 71 | 224.3 | 70 | 1086 | 9.1 | 79 |
| **Rail** | 83.6 | 29 | 97.6 | 30 | 1167 | 2.5 | 21 |
| Total | 290.2 | | 321.8 | | 1108 | 11.6 | |

The Eastern Corridor currently transports mostly domestic traffic (refer Table 8.3). Export/Import (ExIm) freight that should use the Kolkata port system prefer to use remote ports toward the West because of efficiency and capacity challenges, both on the corridor and at the Kolkata port system.

This is confirmed in Fig. 8.16. The Kolkata port system does not currently function as a port for the hinterland states along the Eastern Corridor. The port is mainly a gateway port for the state of West Bengal (where it is located), with two-thirds of imports through Kolkata port destined for West Bengal and 69% of exports originating in West Bengal.

The cargo type segmentation on the Eastern Corridor as illustrated in Fig. 8.17 highlights the modal shift opportunities in mining dry bulk and heavy break bulk (also refer Fig. 8.13). These are natural rail commodities because of flow density offering economies of scale, as well as the lower time sensitivity of these commodities compared with refrigerated and palletized commodities.

Capacity enhancements and improved connectivity at the port should, however, also provide a cheaper alternative for other states along the

**TABLE 8.3** Export/Import and domestic split of freight for India's Eastern Corridor (2015 data; Aritua et al., 2018).

| Flow types | Tons | | Ton-km | | Average distance | Transport cost | |
|---|---|---|---|---|---|---|---|
| | Millions | % | Billions | % | | US$ billion | % |
| Export | 2.5 | 0.9 | 3.8 | 1.2 | 1518 | 0.15 | 1.3 |
| Import | 6.2 | 2.1 | 8.5 | 2.6 | 1358 | 0.34 | 2.9 |
| Domestic | 281.5 | 97.0 | 309.6 | 96.2 | 1099 | 11.11 | 95.8 |
| **Total** | **290.2** | | **321.8** | | **1108** | **11.60** | |

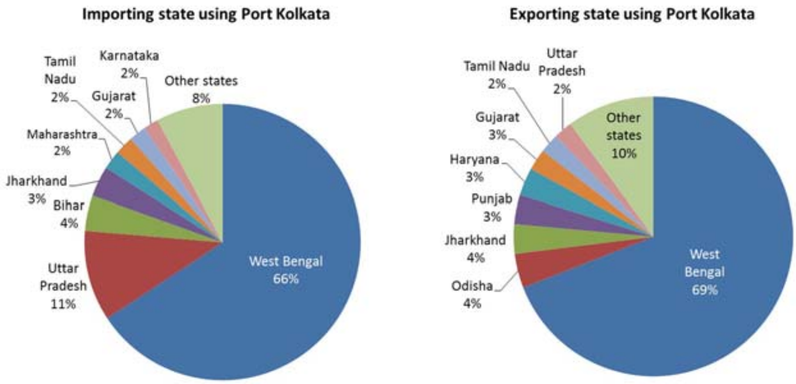


**FIGURE 8.16** Imports and exports at the port of Kolkata (India) by state utilization (2015 data; Aritua et al., 2018).

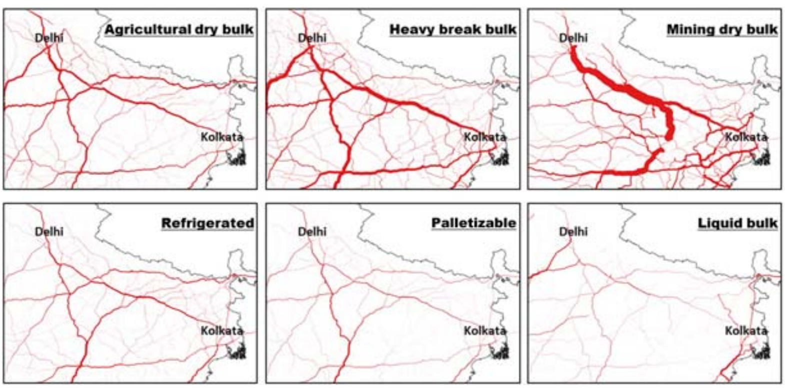


**FIGURE 8.17** Freight flow segmentation according to cargo types on India's Eastern Corridor (2015 data; Aritua et al., 2018).

corridor. If the port of Kolkata were to capture a greater portion of the hinterland imports and exports, an increase in palletizable and refrigerated flows could also be expected. Offering a competitive general freight rail service for these market segments would be a more ambitious goal (in addition to modal shift opportunities in mining dry bulk and heavy break bulk mentioned in the preceding paragraph) that, if achieved, could further reduce logistics costs and road congestion on the Eastern Corridor.

## 3.4 Potential for modal shift on India's Eastern Corridor

The current transport cost for the Eastern Corridor is US$11.6 billion (refer Table 8.2). Initial results show that this can be reduced by US$1.6 billion if rail-friendly freight along the corridor is returned to rail . Many of the freight flows currently using road on the corridor are better suited to rail transportation (refer Fig. 8.17). These flows are typically high-density, long-haul flows of less time-sensitive commodities that originate from or are destined to locations close to the rail line. To shift this freight to rail, issues of efficiency and capacity are being addressed on the Eastern Corridor rail line through upgrading of its services and the design of a targeted commercial strategy, as part of the DFC initiative. In addition to a dedicated corridor focus to solve corridor capacity problems, aspects such as port limitations, connectivity challenges, and the lack of integrated logistics planning also need to be addressed.

The Eastern Corridor has the potential to play a far more prominent role in unlocking logistics efficiencies and trade potential in the landlocked states north of West Bengal. It can also become a robust and prolific hinterland corridor for the two terminals of the port of Kolkata to enable port-led development in the surrounding states. A key element of the proposal is to redesign the Eastern Corridor where it terminates in Kolkata by routing it via a logistics hub. Feasibility studies are required to determine the optimal location of a logistics hub. The logistics hub will require a high-volume, high-speed connection to the rail line at Dankuni, a high-volume, accessible truck terminal, and efficient intermodal transfer facilities. (Capacity for other supply chain services such as storage, customs clearance, and value-added services would also be beneficial but is not required right from the start.). The logistics hub also needs to be connected to the Kolkata Dock System[12] directly, circumventing the city center of Kolkata completely. A rail or inland waterways shuttle is suggested as a high-speed, high-volume solution. An accessible, high-speed connection from the logistics hub to the Haldia Dock Complex[12] will also be necessary, but this may very well remain a road solution. If these conditions are met, a further US$2.1 billion of costs can be saved (these potential savings are detailed in Table 8.4). Modal shift on the Eastern Corridor will, therefore, only contribute 44% of the total potential of $3.7 billion saving that can be achieved by an integrated corridor design.

### 3.5 Examples of prefeasibility analysis on the Eastern Corridor

The six interventions summarized in Table 8.4 relate to modal shift[13], attracting freight to the Kolkata port, and reducing congestion in and around Kolkata. Despite these interventions, the majority of freight will remain on

[12] The Kolkata port has two dock systems, namely, the Kolkata Dock System in Kolkata and a deep water dock at Haldia Dock Complex in Haldia.

[13] Theseare high-level estimates, which will continue to be updated as more information becomes available.

**TABLE 8.4** India's Eastern Corridor savings potential in US$ million—mainly related to improved utilization of rail and improved port system (2015 data; Aritua et al., 2018).

| Strategic objective | Intervention | Description | Dedicated freight corridor (US$ millions) | Logistics hub and dedicated link | |
|---|---|---|---|---|---|
| | | | | (US$ millions) | % |
| Intermodal corridor solution | Modal shift within corridor | Rail-friendly freight on road shifts to rail (origin and destination are within the corridor) | 1647 | | 44 |
| Kolkata as gateway for Uttar Pradesh, Jharkhand, and Bihar | Hinterland port shift of rail-friendly freight to rail/intermodal | Freight that can use rail will shift to the closer port of Kolkata | | 496 | 13 |
| | Hinterland port shift of freight on road (remains on road) | Freight that cannot use rail (because of the location of load points) but will shift exports away from Western ports because of the | | 868 | 23 |

(*Continued*)

**TABLE 8.4** (Continued)

| Strategic objective | Intervention | Description | Dedicated freight corridor (US$ millions) | Logistics hub and dedicated link | |
|---|---|---|---|---|---|
| | | | | (US$ millions) | % |
| | | improved link and shorter distance | | | |
| Improve access and reduce congestion | Corridor-city link | Freight shifts from road to rail because it can more easily reach the port on rail/intermodal | | 549 | 15 |
| | Kolkata city logistics improvement | The hub and link will also have a concomitant positive alleviation effect on inner-city congestion | | 146 | 4 |
| | Terminal-port link | Reduce current ExIm costs because of reduced congestion | | 39 | 4 |
| Total | | | 1647 | 2097 | |

*ExIm*, Export/Import

road and, exactly because of these interventions, the road traffic on the Eastern Corridor is expected to increase (as more ExIm freight uses the more efficient corridor). Therefore the systemic issues that plague road transport in India in general also need to be addressed. The details contained in India's FDM allow the assessment of what the potential benefit could be on the Eastern Corridor resulting from road efficiency interventions. Although this study is only a prefeasibility analysis (i.e., it does not detail the cost/investment side of cost–benefit analysis), the results are illustrative of how the disaggregated national FDM can be interrogated to guide decision-making.

In total, US$ 1.7 billion per annum could be saved through six systemic interventions listed in Table 8.5. Many of these interventions require industry-wide collaboration and/or costly infrastructure development — the cost and practicality of which also need to be taken into account. The take

**TABLE 8.5 Examples of prefeasibility analysis on India's Eastern Corridor—mostly relates to more efficient road transport, as well as roadrail collaboration (Aritua et al., 2018).**

| Intervention | Mode | Rationale | Savings per annum (US$ millions) |
|---|---|---|---|
| Improved training of truck drivers | Road | Will improve distance that trucks can be driven and fuel consumption and reduce externalities such as accidents | **271** |
| Add lanes to highways | Road | Will reduce congestion and therefore increase distances that trucks can be driven | **437** |
| Replace vehicles with a newer fleet[a] | Road | Improved fuel consumption and reduced emissions | **−111** |
| Improve truck turnaround times in ports | Road | Improved truck utilization | **25** |
| Eradicate state border post delays | Road and rail | Improved truck utilization | **547** |
| Consolidate flows through improved collaboration | Road and rail | Reduce empty haul | **509** |

[a] *This saving will depend on the cost of new vehicles. With current information, it does not result in a positive answer to shift to newer vehicles. Some truckers have suggested that only the engines could be replaced and not the full bodies.*

out of this analysis is that once detailed freight flow data and costing is available, more informed analyses can be conducted, leading to data-driven decisions.

The model outputs also illustrated that a planned freight terminal in Varanasi (on the Eastern Corridor) could capture 39 million tons of intermodal freight rather than the 1 million tons originally estimated (Dash, 2017).

## 4. Model validation — background and next steps

In emerging economies, rail typically has a very low market share (actual rail data are used in the FDMs), and road transport is very fragmented. No actual data, therefore, emerge over time that the aggregate flow outputs can be validated against. (In the case of imports and exports, where data is captured, the actual data are also used in the FDMs to improve accuracy.) As described, the FDMs are hybrid input data models situated on the demand side of the transport. Model validation (triangulation) can be done using the following data points:

1. Using flow categories and a route assignment approach, it is possible to segment freight flows into various categories, including, for instance, corridors, which was possible for both South Africa and India. The FDM, therefore, estimates the volume of freight that each country uses on each corridor. This provides the first data point for a triangulation exercise.
2. A second data point for triangulation can be provided by surveying freight forwarders, but rather than a detailed commodity flow survey (which is exactly the expensive and difficult undertaking that is usually not possible or at least possible quickly in an emerging economy context), the purpose here would be the determination of load factors and empty haul. By applying load factors and empty haul to estimated freight volumes (obtained during step 1) the number of vehicle movements per period can be estimated.
3. The third data point is comparing freight supply, that is, actual truck movements, to the estimated freight demand (applying load factors and empty haul from step 2 to commodity flow demand from step 1). Freight supply can be obtained from vehicle counts and does not require intercept surveys. In both India and South Africa, national highway agencies conduct vehicle counts at various locations. The model is deemed to fit if the supply and demand comparison is close.

In the case of South Africa, comparisons between steps 1 and 3 mentioned earlier were done toward the end of the first lustrum of the model — the fit was acceptable, and anomalies could be explained (refer CSIR, Stellenbosch University and Imperial Logistics, 2011). A detailed confidential analysis of freight flow estimates against Transnet actuals was done in

2012, and the fit was significantly better than internal forecasts. As described in Textbox 1, Chapter 4, Van Eeden (2018) validated the content-based container quay wall projection (this is a submodel of the FDM$^{TM}$) against a GDP-multiplier quay wall projection. The content-based model was found to predict the container volumes more accurately: the content-based model's error remained within 7% of the actual recorded volumes over the 5-year forecast, whereas the GDP-multiplier overstated capacity by more than 20% over the same 5-year horizon.

Given the fact that all known supply and demand data in the economy, available actual freight flows (typically rail and large industry flows), and actual import and export data are used to populate the supply and demand tables, the stakeholders in both case study countries show a high level of confidence in the data. This process of supply, demand, and flow calibration also entails interaction with a large number and variety of role-players, which allow for verification of input and output data.

In India, the first FDM was developed in 2016–17. Validation against truck counts is on the research agenda for subsequent phases. For South Africa, funding is being sought to update the triangulation data, as described in steps 1 to 3 mentioned earlier in this section.

## 5. Concluding remarks

This chapter showcased the application of disaggregated national FDMs in emerging economies South Africa and India to inform macro- and meso-logistics decision-making. The relevance of these FDMs is the provision of a spatial and sectoral quantification of all freight transport market segments in the economy; the market spaces can therefore be accurately identified, and infrastructure investments and service delivery can be costed, targeted, and aligned with national infrastructure master planning. These data-driven initiatives can support the unlocking of logistics efficiencies to stimulate economic growth while addressing pressing socioeconomic challenges. A description of both nations' freight transport landscape highlighted similar challenges of inefficient transport supply, the disproportionate market share of road on long-distance, high-density corridors, and the resulting logistics costs impacts.

In the case of South Africa, the priority initiative to address these challenges is the development of three intermodal hubs in Gauteng, Cape Town, and Durban and the implementation of domestic intermodal solutions on the country's two key general freight corridors, Gauteng–Cape Town and Gauteng–Durban. The delay in implementation of intermodal solutions can be attributed to the inability of public and private logistics service providers to yield to collaborative approaches and agree on cost–benefit allocations, exacerbated by political apathy and misallocation of state funds. The revitalization of rural branch lines is also a key focus area for poverty alleviation because of its potential impact on rural development and improved spatial planning, currently hampered by excessive urbanization. The outputs of South Africa's FDM$^{TM}$ have also had a significant impact on Transnet's strategic direction and rail and port investments, which are key components of providing more sustainable solutions to service future freight transport demand. The outputs have also played an important role in facilitating data-driven national policy debates.

In the case of India, timely access to data and buy-in from local researchers were major challenges at the outset of the research, but as the outputs are being shared more widely, there is an increased understanding of the importance of this work. The outputs from the FDM enable integrated planning between road, rail, port, and inland waterways to support the dedicated freight corridor project for addressing capacity and connectivity challenges. This includes the creation of logistics hubs to facilitate seamless integration between modes, relieve inner-city congestion, and support hinterland development. As a case in point, the outputs of India's FDM resulted in an integrated proposal for an extended gate for the port of Kolkata, a logistics hub outside of Kolkata with a high-volume link into the city and a link to an inland terminal at Varanasi to achieve some of these objectives. This integrated proposal has been accepted by the government — the Varanasi project has been announced in the press, and land for the extended gate project has been earmarked at Balagarh, some 50 km north of Kolkata where the dedicated freight railway, highway, and waterway meet. The next level of planning is underway.

In both countries, a virtuous cycle, therefore, emerged — high-level quantification is developed with little data to inform responses to pressing questions in the logistics landscape. This leads to buy-in and increased participation by users, facilitating access to data and the quantification of more pertinent questions and scenarios to facilitate macrologistics planning and decision-making.

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Chapter 9

# Belt and Road Initiative: more competition between sea and rail? A generalized cost approach

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## Highlights

- Respecification of a port and logistic change model.
- Application of the respecified model to inform infrastructure decisions on the Belt and Road Initiative.

## 1. Introduction

Eurasiatic rail freight transport has experienced a dramatic growth during the past years. During the first decade of the new millennium, there was no frequent rail connection yet between China and the European continent. A negligible amount of goods was transported by rail between China and Europe via the Trans-Siberian Railway Link. The connection featured high transit times and a lack of reliability. The US Chamber of Commerce in 2006 summarized the situation as follows: "*The current land transport connections between Asia and Europe do exist, but they have no viable share of the commercial market*."

Western companies, at the end of the 2000 decade, gradually started experimenting with direct Eurasian rail freight connections. DB Schenker launched a weekly link between Shanghai and Duisburg in 2009. Because of increasing wage costs in the Chinese coastal provinces, Hewlett-Packard (HP) decided to move its production facilities inland, to Chongqing in particular. This move, of course, had a substantial impact on the HP supply chain

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because goods could now reach Europe over land within 25 days, instead of 37 days via sea. Hence, HP started researching the feasibility of a direct, frequent rail connection between Chongqing and the European continent. As part of its "Go West" strategy, the Chinese government supported this initiative, but the co-ordination with policymakers of other concerned countries turned out to be less evident.

The launch of the Eurasiatic Economic Union in 2011 was a turning point. That implied that transit countries Kazakhstan, Russia, and Belarus became a customs union. HP's pilot phase ended successfully at the end of 2011 and became a weekly rail freight connection between Chongqing and Duisburg a year later. This service was a block train, in other words, a train going directly to its final destination and reserved by one sole customer.

Today, there are three main land corridors between China and Europe (Fig. 9.1), of which two actually finish in the European Union (EU; Garcia Herrero and Xu, 2017). The northern corridor connects to the Trans-Siberian rail line from either Mongolia or Manchuria. The middle corridor has several variants, but these all cross Kazakhstan. Finally, there is a strong will in Central Asia and Caucasus to develop a southern corridor. The latter is also called the Trans-Caspian Corridor and could be a potential route for European food producers to avoid the Russian sanctions. Nevertheless, there are no frequent connections yet between China and Europe on this southern route. This is mainly because of the poor state of the infrastructure on that connection. The majority of the Eurasian rail flows, 71% in 2018, passes by the middle corridor, up from only 12% in 2011 (Vinokurov et al., 2018; Kenderdine, 2018). The latter implies that the northern route has lost relative importance.


**FIGURE 9.1** The three main Asia–China rail corridors. Source: *Hillman, J., 2018. The Rise of China-Europe Railways. Center for Strategic and International Studies, Washington, DC. Retrieved from https://www.csis.org/analysis/rise-china-europe-railways.*

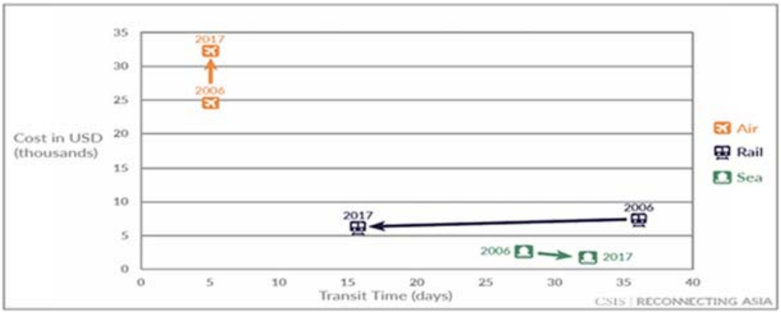


**FIGURE 9.2** Evolution of transit times and costs of the various transport modes connecting China to Europe over the period 2006–17. Source*: Hillman, J., 2018. The Rise of China-Europe Railways. Center for Strategic and International Studies, Washington, DC. Retrieved from https://www.csis.org/analysis/rise-china-europe-railways.*

Overall, since 2011, rail traffic between China and Europe experienced a spectacular growth. Volumes increased from 25,000 TEU in 2014 to 175,000 TEU in 2017. Fig. 9.1 shows the main points of origin/destination on the considered routes. In China, larger rail hubs are located rather inland, mainly because of the competition with maritime transport in the coastal provinces.

Fig. 9.2 shows that the competitive position on the China–Europe corridor of rail versus air and sea in terms of transit times, and costs have improved over the 2006–17 period. Rail featured a significant drop in transit time while also the average price charged to users declined slightly. Sea transport also featured a drop in prices charged, but its transit time went up, mainly because of slow steaming. Air transport is clearly the fastest with no change in the transit time but with an increase in its rates. Hence, rail is the only mode to which over the considered period managed to improve both its transit time and cost.

All the above has to be put into perspective of course, given total trading volumes between China and the EU. China, which is the biggest exporting country in the world, is also the biggest partner of the EU for the latter's imports, representing 20% of total import flows for 2018, or EUR 395 bn (Fig. 9.3). For EU exports, China is the second biggest trading partner, with 11% of the EU export share for 2018, or USD 210 bn, preceded by the United States. The EU's resulting trading deficit with China amounted to 185 billion USD in 2018. Assuming that the cargo of one container (FEU) from China to Europe values EUR 147,785 in 2019 (Damadoran, 2018; Hurkmans, 2018), the total transported volume of 175,000 TEU from China to Europe represents about EUR 25 bn, or only 6% of the total trading volume in value between China and Europe. The vast majority of cargo still uses maritime transport, whereas mainly, the smaller portion of time-critical goods today use air.

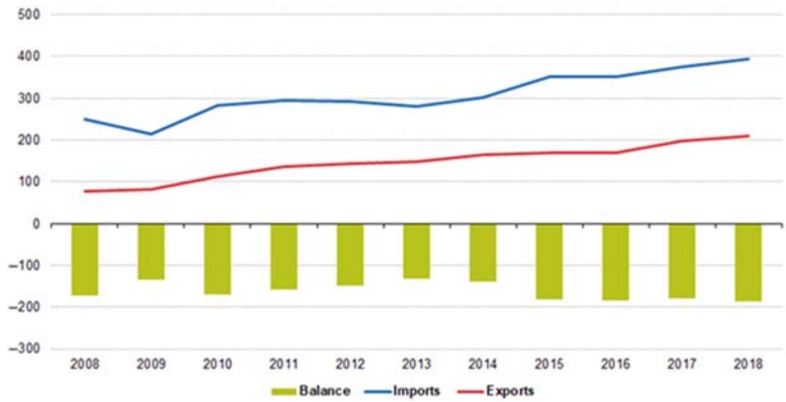


**FIGURE 9.3** Imports, exports, and balance for trade in goods between the EU-28 and China, 2008−18, billion EUR. Source*: Adapted from Eurostat, 2019. China-EU − International Trade in Goods Statistics. Retrieved from https://ec.europa.eu/eurostat/statistics-explained/index.php/China-EU_-_international_trade_in_goods_statistics#EU-China_trade_by_type_of_goods.*

The most imported manufactured goods in value in 2018 were machinery and vehicles (53%), followed by other manufactured products (39%) and chemicals (5%). Strikingly, the same commodities are also the ones most exported from the EU to China. The latter might offer the potential for finding backhaul cargo: the same train could take back a similar type of cargo, without the need for changing or cleaning wagons. Over time, we observe that the total value of most transported cargo types from China to Europe has been increasing since 2008. But especially “machinery and vehicles” and “other manufactured goods” have seen strong increases. That indicates that the average value of cargo being imported from China into Europe is on the increase. Both observations will be relevant for further scenario selection (Eurostat, 2019).

The question is what the future will bring for rail compared with the other modes on the China−Europe connection: to what extent will rail become a real competitor? This chapter deals with that topic. It does so by combining literature search, scenario development, and cost modeling. For the latter, there is a challenge in terms of data availability for a number of countries along the abovementioned corridors, especially those outside Europe. The purpose of this chapter is explicitly not to do trade modeling so as to come to aggregate transport flows for the different modes on the connection but solely to compare the basis for such mode and corridor selection, namely, the unit generalized costs of transporting.

Section 9.2 looks at the investment plans that are on the table for rail, as part of the broader geopolitical strategies, so as to provide input for the scenario selection. Section 9.3 addresses the challenges and risks related to elements of those plans, again supporting the scenario selection. Based on that combined information, Section 9.4 develops a number of scenarios of future rail development on the corridor, which are subject to cost analysis in the further sections. Section 9.5 presents the modeling methodology for the calculation of the total chain costs. Section 9.6 applies this methodology to calculate and compare the total cost for the different transport alternatives for the selected connections. Finally, Section 9.7 wraps up the findings in a conclusion.

## 2. Rail policies and plans on the China–Europe corridor

The sudden growth of the Eurasiatic rail freight connections can be attributed to a number of political, economic, and technical factors. There is a general consensus, although this transport mode could not have developed as quickly if China's political and financial support would not have been as extensive as it was.

Chinese President Xi Jinping pronounced himself in fall 2013 in favor of economic integration on the Eurasiatic continent. In Kazakhstan, he pleads for launching the "Silk Road Economic Belt." One month later, he pleads for setting up a regional cooperation body, called "The Maritime Silk Road." Together, these were the main components of the Chinese "One Belt One Road" (OBOR) initiative (Huang, 2016; Wuthnow, 2017). In 2016, President Xi Jiping expanded his strategy with renaming the wider initiative into Belt and Road Initiative (BRI). This is especially meant to stress the fact that multiple corridors are involved in establishing much closer trading relationships between various parts of the world, and that the initiative is about much more than just establishing a new/revived land connection (Wang, 2016).

The president's foreign policy is not totally disruptive though but continues along the foreign infrastructure development lines of the past 25 years. These had been set up in Central and Southeast Asia and concerned the energy and transport sector. Several of these projects have, in the mean time, been put under the OBOR framework, such as the Chongqing–Duisburg rail connection or the Bangladesh–China–India–Myanmar economic corridor, started up in 1996 (Wuthnow, 2017).

China was not the only player in the Eurasiatic development area. Since 1992, the EU has launched a number of projects that are part of the "Transport Corridor Europe-Caucasus-Asia" framework. Furthermore, in 2011, the American Minister of Foreign Affairs Hillary Clinton announced the "New Silk Road Initiative," which would integrate Afghanistan better with the other Central-Asiatic economies. Korean President Park Geun-hye announced in 2013 that his country was about to launch a "Eurasia initiative" to improve regional connectivity. The fact that Belarus, Russia, and Kazakhstan became a customs union implies that only three customs zones need to be passed between China and Europe.

What makes OBOR and even more BRI different from the preceding initiatives is its geographical size and scale. The framework foresees six economic corridors that are to connect China to its neighboring countries. Table 9.1 provides an overview of the corridors and the most prominent projects. Sixty-three countries are involved, among which 18 are European (Garcia Herrero and Xu, 2017). Moreover, OBOR would mainly be

**TABLE 9.1 OBOR corridors, partners, and main projects.**

| Corridor | Partners | Main projects |
|---|---|---|
| Bangladesh–China–India–Myanmar | Bangladesh, India, Myanmar | • Padma bridge (Bangladesh)<br>• China–Myanmar LNG pipeline |
| China–Central–Asia–West–Asia | Iran, Kazakhstan, Kyrgyzstan, Kuwait, Qatar, Saudi Arabia, Tajikistan, Turkey, and Uzbekistan | • Renewal Manas airport (Kyrgyzstan)<br>• High-speed rail network Turkey |
| China–Indochina | Cambodia, Vietnam, Thailand, and Laos | • China–Laos rail connection<br>• Lancang–Mekong shipping route |
| China–Pakistan | Pakistan | • Karakorum motorway<br>• Gwadar port |
| China–Mongolia–Russia | Mongolia, Russia | • Altai LNG pipeline<br>• Altanbulag–-Ulaanbaatar motorway |
| Eurasiatic Land Bridge | Belarus, Bulgaria, Czechia, Greece, Hungary, Kazakhstan, Poland, Russia, Serbia, and Slovakia | • China–Europe rail freight transport<br>• Piraeus port |

*OBOR*, One Belt One Road.
*Source*: Adapted from Lau, S., Ling, N.B., Rathbone, M., Wijeratne, D., Yau, J., Wong, G., 2017. Repaving the Silk Roads. PwC growth markets centre. Retrieved from https://www.pwc.com/gx/en/growth-markets-centre/assets/pdf/pwc-gmc-repaving-the-ancient-silk-routes-web.pdf; Wuthnow, J., 2017. Chinese perspectives on the belt road initiative: strategic rationales, risks, and implications. China Strategic Perspectives, Washington, DC. Retrieved from http://inss.ndu.edu/Portals/68/Documents/stratperspective/china/ChinaPerspectives-12.pdf.

financed through multilateral development banks (USD 100bn by AIIB) on the one hand, and Chinese state banks and dedicated funds (for instance the Silk Road Fund with USD 50bn) on the other (Lau et al., 2017; Wuthnow, 2017; Callahan, 2016). Nevertheless, synergies were sought with other continent's initiatives, for instance, the European Juncker investment plan. To that purpose, the Sino-European Connectivity Platform was launched, where Trans-European Transport Network funding allows matching (van der Putten et al., 2016). Similarly, the Kazakh government saw BRI as an opportunity to develop itself as a logistics hub in the region, especially after the 2014 Russian crisis and dropping oil prices, which both hit hard for Kazakhstan. The Kazakh "Nurly Zhol" plan not only foresees large infrastructure works, valued at 9 billion USD, but also the development of 10 free trade zones, so as to better accommodate transit traffic (Kenderdine, 2018).

China also financially heavily supports users who apply Euroasiatic connections. Hillman (2018), Forbes (2018), and Vinokurov et al. (2018) indicate that per container, subsidies of between USD 1000 and USD 5000 apply. Between 2011 and 2016, about USD 300 million of subsidies was awarded. That amount is relatively limited in comparison to the USD 113 billion the country invested in rail infrastructure in 2018 only.

The future success of this OBOR policy is highly determined by the strength of its motivation. It appears that stakes for China are high, both from a geopolitical as well as a geoeconomic perspective.

Geopolitics in this case encompasses three submotives: favoring regional stability, safeguarding China's energy imports, and increasing the Chinese sphere of influence on the Eurasiatic continent (Cai, 2017).

With respect to regional stability, OBOR is to create a more stable political climate in the Western as well as Southern Chinese periphery. President Xi Jinping aspires for Eurasia to evolve toward a "community of shared interests." This concerns in the first place its own western Province of Xinjiang. Economic development should reduce revolting sentiments among the local, mainly Uighur, population. Furthermore, it also concerns other countries, especially India and in South Asia, where common OBOR interests might take away territorial disputes (Wuthnow, 2017).

Energy ensurance has been a topic of increasing strategic importance for China, as its dependence on particularly oil and gas increased seriously in line with economic growth. In 2014, China became the world's largest energy importer. At the same time, about 80% of China's energy imports pass through the Malacca Strait, which makes these flows very vulnerable to blockings (Cai, 2017; Engdahl, 2017).

The third and last geopolitical issue concerns the balance to be struck between the Chinese desire to increase its sphere of influence on the one hand and the US "China Containment Policy" on the other. A possible equilibrium then is a focus on its Western periphery, where US interests are more limited (Huang, 2016; Wuthnow, 2017; Stratfor, 2018).

On the geoeconomic side, again three sub-motives for OBOR success are mentioned: regional–economic development, overcoming its own middle-income trap, and accommodating overcapacity in its production system (Cai, 2017).

As to regional–economic development, the growing inequality between interior, western Chinese regions and its coastal area are a source of increasing concern. For example, Shanghai's gross domestic product (GDP) is about five times as high as that of the western Gansu province. Despite the Chinese "Western Development Strategy," the share of the western provinces in the Chinese GDP has increased only from 17.1% in 2000 to 18.7% in 2016. The result of this lasting public financial support is that the four western provinces (Xinjiang, Tibet, Qinghai, and Gansu) score the lowest on the China Economic Research Institute's Free Market Index, featuring lots of state-owned enterprises. To remedy this failing policy, the Chinese government has decided to shift away from putting public money into the provinces directly to connecting them through OBOR. The connections do not target only the western provinces: a large part of China is implied in OBOR-related initiatives, as shown in Fig. 9.4 (Huang, 2016; Cai, 2017).

China's middle-income trap is a second sub-motive for investment in OBOR. Through increasing wages and land rents, China has lost part of its comparative advantages against other production countries in the world. Its government, therefore, wants to reinforce its focus on "high-end" products, which it hopes that OBOR can contribute to making those products attractive to buyers along OBOR corridors (Cai, 2017; Hsu, 2017).

Third and finally, as a reaction to the financial–economic crisis, the Chinese government had heavily stimulated the production of steel, cement, and aluminum (Garcia Herrero and Xu, 2017). China's steel production capacity, for instance, rose from 512 million tons in 2008 to 803 million tons in 2015. This increase alone is bigger than the total production of the United States and the EU together in 2015. However, at the same time, interior and foreign demand started to drop. The Chinese government, therefore, hoped that the production of lower value goods could be pushed to neighboring countries, with OBOR connections enabling access to these production locations. At the same time, China would focus on higher value goods production, with OBOR allowing for access to markets. However, it is questionable whether the real cause of the overcapacity is there or rather the global fall in demand because of a slowing economy (Cai, 2017). In any case, Zhai (2018) shows that the BRI initiative is modeled to increase the world's GDP by 1.3% by 2030.


**FIGURE 9.4** Involvement of Chinese provinces in One Belt One Road plans. Source*: Cai, P., 2017. Understanding China's BRI Initiative. Lowy Institute, Sydney. Retrieved from https://www.lowyinstitute.org/publications/understanding-belt-and-road-initiative.*

Next to the stimulators of the BRI policy, as reviewed in this section, there are also a number of potential obstacles. They will be introduced in the next section.

## 3. Challenges and risks in Chinese Belt Road Initiative rail policy

The Chinese government, in its implementation of the BRI policy, encounters a number of obstacles. They can be summarized as mistrust against China, instable governments in neighboring countries, and big project risks (Cai, 2017).

First of all, there is significant mistrust among the countries participating in BRI. The Indian government, for instance, is skeptical about BRI because of the historical animosity between the countries, and the fact that the rail connection runs through the disputed areas of Jammu and Kashmir (Cai, 2017). Moreover, out of discontent with the existing financial institutes, dominated by the United States and Japan, China had decided to set up the "Asian Infrastructure Investment Bank." This multilateral development bank features 64 members, all situated along the BRI axes. The bank is heavily dominated by China, which again leads to suspicion among the other bank members. There is also mistrust on China exporting its excess capacity (Shambaugh, 2016; Huang, 2016; Garcia Herrero, 2017) and about the mixed track record of Chinese investment projects in developing countries

(Callahan, 2016). Mistrust among EU countries against BRI would seem misplaced according to results by Garcia Herrero and Xu (2017), who show that the EU would be the biggest winner of all BRI countries from a trade increase point of view, much more than China or other involved countries. It must be mentioned that the positive impact for Europe of a transport cost decrease, thanks to BRI, is smaller when combined with the establishment of a bilateral trade zone.

Furthermore, a number of countries involved in BRI suffer from government instability. In some of the key countries, terrorist insurgency from separatist or religiously extremist groups creates troublesome development situations (Raza, 2017).

Third, risks related to projects of this scale are first of all of financial nature. The increasing Chinese debt does worsen this status (Callahan, 2016). The IMF showed itself particularly worried about the Chinese situation: "the Chinese credit-to-GDP ratio is 25% above the long-term trend, while corporate debt has reached 165% of GDP and household debt is increasingly linked to asset-price speculation. The buildup of credit in traditional sectors has gone hand-in-hand with a slowdown of productivity growth and pressures on asset quality" (The Guardian, 2017). The debt status may be worsened by the "white elephant" character of a number of the BRI projects. Moreover, moral hazard may be at play: some countries may be interested in using Chinese financing, not having the intention to actually pay back. Chinese financiers also seem less inclined to develop favorable conditions for BRI projects (Huang, 2016; Cai, 2017).

## 4. Scenarios for future development

For the future development of BRI routes and to determine the relevant applications and scenarios to analyze in this chapter, a comparison is made in Table 9.2 of the various sections and their potential and barriers. The routes are mapped in Fig. 9.5.

There are border crossings on the various routes that make transit times increase, especially on the Southern route. For instance, it takes 17–20 days to transport a container by rail from Chengdu to Istanbul, whereas one needs only 12–15 days from Chengdu to Duisburg. A supplementary barrier to that route is the Caspian Sea, which imposes intermodal transport partly by water, which further increases transit time and cost. For instance, there is only one weekly container feeder service between the Azeri port of Alyat and the Kazakh port of Aktau. Its transit time is about 36 hours. Furthermore, handling time of one loaded train in both ports is estimated at 24 hours (Schwilling, 2017; Trans-Caspian International Trade Route TITR, 2018).

**TABLE 9.2 BRI sections and their potential and barriers.**

| Route | Capacity and characteristics |
|---|---|
| 1) Via Alashankou/Khorgos | • Good infrastructure<br>• High reliability<br>• Sufficient capacity |
| 2) Via Manzhouli/Zabaykalsk | • Good infrastructure<br>• High reliability<br>• Limited capacity Zabaykalsk |
| 3) Via Erenhot (Mongolia) | • Alternative for route 2, with additional border crossing<br>• Limited infrastructure Mongolia |
| 4) Via Vostochny (Russia) | • Good infrastructure<br>• High reliability<br>• Suitable for traffic from South Korea and Japan |
| 5) Via Dostyk/Khorgos and Baku | • Alternative for South European destinations<br>• Caspian Sea needed (intermodal) |
| 6) Via Khorgos/Tashkent/Tehran | • Lacking infrastructure<br>• Political instability |
| 7) Via Tehran and Baku and Moscow | • North–South route (India–Europe traffic)<br>• Under construction |

*BRI*, Belt and Road Initiative.

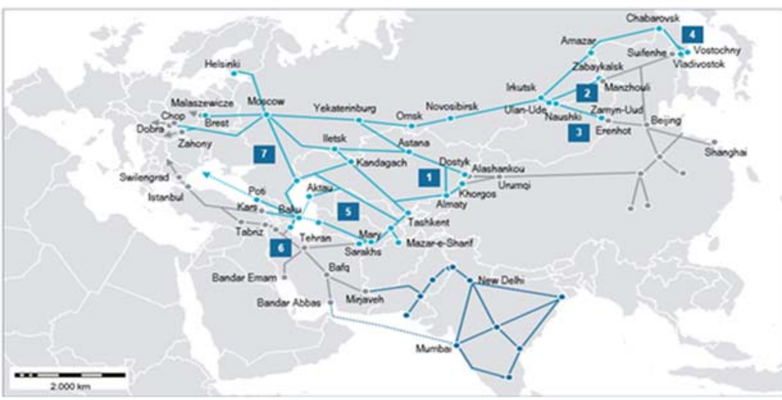


**FIGURE 9.5** Belt and Road Initiative land sections and their border crossing points.

One also has to mention that Chinese policymakers show an interest in creating a "land–sea express route." This route contains both a longer run maritime and land component, as goods are first transported by ship to the Greek port of Piraeus, to continue their voyage to Central or Western Europe by rail. This route would reduce the classical maritime route between China and mainland Europe by about 4500 km, making the transit time shrink by between 8 and 12 days.

However, to date, hinterland connections from Piraeus are still limited to two corridors: Corridor IV, along Bulgaria and Romania, and Corridor X, along Serbia and Macedonia.[1] Corridor IV consists of single track and allows for speeds of 60 or 70 km/h. Transit time from Thessaloniki to Budapest therefore is 26 hours. Corridor X is 300 km shorter but features even stronger speed limitations because of lacking capacity, resulting in a transit time between Thessaloniki and Budapest of 49 hours. Nevertheless, because of the increasing activities by Chinese China Ocean Shipping Company (COSCO) in the port of Piraeus during the past years, the development of the concerned corridors was heavily stimulated. COSCO started operating block train services direction of Central Europe. These services aim at multinationals that have a distribution center at the port, including HP, Sony, Foxconn, Hyundai, and Huawei. Since the end of 2017, eight freight trains a week operate the service. Corridor IV is also among the TEN-T core projects, which implies that priority European funding is dedicated to the project.

The path toward improving the rail connections is not always smooth though. For corridor X, the Serbian government wanted to collaborate with Russian Railways and China Railway Group Limited. However, the European Commission intervened, as this was not according to the European granting rules. Further on, some European officials see the growing Chinese involvement in Central and Eastern Europe as a threat and part of a Chinese "divide and rule strategy."

For the abovementioned reasons, the choice is made to include five different routes between Asia and Europe in the analysis of this chapter:

- The classical maritime route with call at the port in the Hamburg–Le Havre range.
- The middle rail connection n°1 via Kazakhstan (Khorgos).
- The northern rail connection n°2 via Russia (Manzhouli).
- The land–sea route via Koper.[2]
- The land–sea route via Gdansk.

1. More information on these corridors can be found at the World Bank: http://projects.worldbank.org/P108005/corridor-x-highway-project?lang = en.

2. The port of Koper was selected as the South European entry for maritime flows from China because of its addition in 2018 to the Silk Road network, given its very good European hinterland connections. It features among others, on average, as many as 70 freight trains daily connecting Koper and the largest economic centers in Central and Eastern Europe (Port of Koper, 2018)

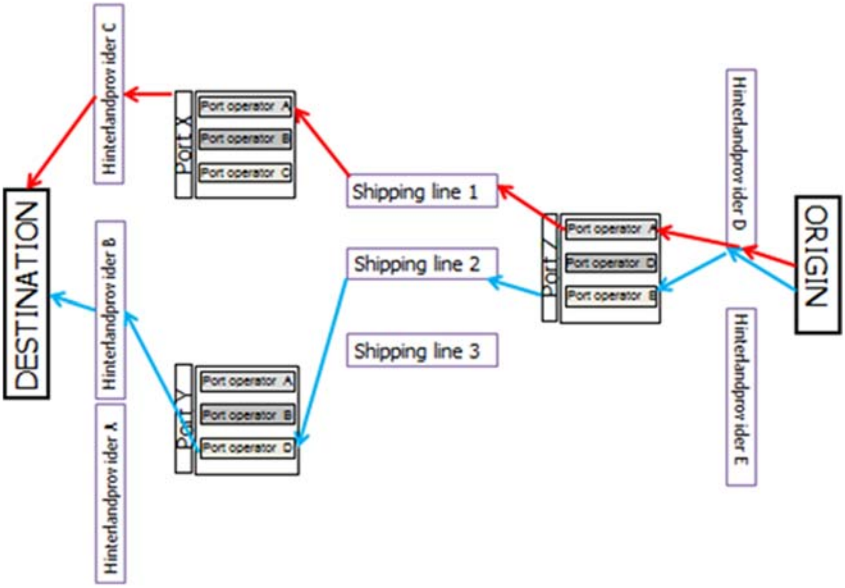


**FIGURE 9.6** Supply chain view on port competition. Source*: Adapted from Meersman, H., Van de Voorde, E., 2012. A New Approach to Structuring Port Competition – Course Presentation. MIT, Boston.*

For the maritime routes, the last-mile land part in Europe is assumed to be performed by road for the ports of Gdansk and Koper, whereas for Rotterdam, all three hinterland modes (road, rail, and inland waterways) are considered. In China, all three possible land modes (road, rail, and inland waterways) are considered if available.

Per transport chain[3] the most suitable routes will be selected and compared.

## 5. Chain cost modeling methodology

To compare the five routes, a model is applied that allows calculating the total generalized chain cost. This model was in the first version developed in the study by van Hassel et al. (2014). In this model, the total supply chain, including maritime transport, the port process, and hinterland transport, is taken into account. The main reason to lay the emphasis on the supply chain is that container liners, seaports, and land transport modes will compete along these supply chains. This is illustrated in Fig. 9.6, where the chain with the lowest overall generalized cost will be the most attractive chain.

3. A transport chain has an origin in Asia (province level) and a destination in Europe (NUTS-2 level) or vice versa.

This approach by van Hassel et al. (2014) was chosen, as it not only allows calculating the generalized cost for a total logistics chain, in which ports play a vital role, but also comparing different scenarios, with different modes, port, and hinterland origins and destinations. Other methods, mentioned in the literature review in the study by van Hassel et al. (2016b), do not have this ability, and therefore this model is used to address to proposed research questions.

The model by van Hassel et al (2014) allows calculating the generalized chain cost from a selected point of origin, via a predefined container loop to a destination point. Fig. 9.7 gives the general overview of the developed model.

To calculate the chain cost, first, the successive ports in a container loop have to be defined. This loop will determine the maritime part of the chain and encompasses the maritime leg of the supply chain.

In the model, different aggregated hinterlands are connected via a route with the relevant ports (bold lines in Fig. 9.7). The aggregated hinterlands are defined as a summation of different smaller geographical areas, which in Europe correspond to NUTS-2 areas. Each aggregated hinterland is served by at least one and usually by several ports. Each port is built up of a set of terminals, all of which have their own set of characteristics. From each port terminal, the hinterland connections via road, rail, and inland waterways (if applicable) to all the disaggregated hinterland regions are incorporated into the model.

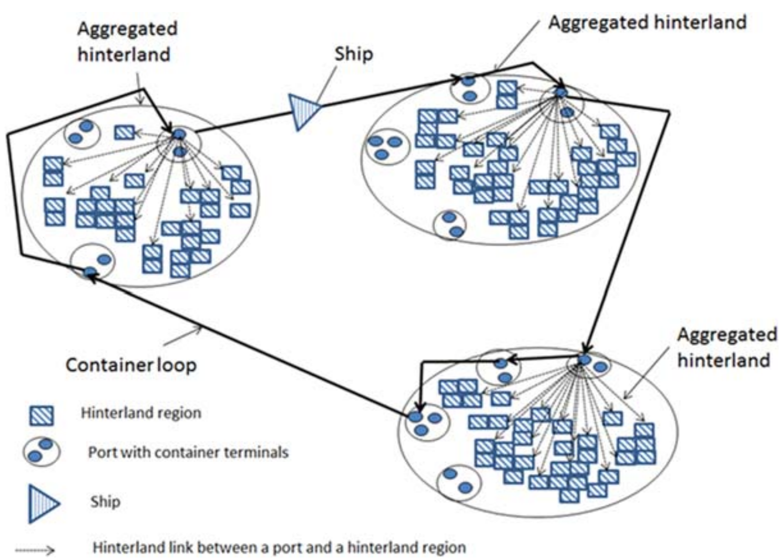


**FIGURE 9.7** Structure of the chain cost model. Source*: Adapted from Own creation.*

From each terminal in a port, the distances toward the hinterland via road, rail, and inland waterways (if available) are incorporated in the model. This allows calculating the cost per mode from a terminal to a hinterland destination.

A chain is defined as a route from an area in a specific aggregated hinterland to an area in another aggregated hinterland. A chain, therefore, has a beginning and an end. To calculate the chain cost from the point of origin to the point of destination, the model not only calculates the total cost of the ship but also incorporates the cost of transporting a container from a hinterland area to a port on both ends of the chain, the cost of a container in the port phase (port dues, pilotage, container handling, etc.) on both chain sides, and the cost of transporting via sea the container from the port of loading to a port of unloading.

The hinterland model can be used to calculate the hinterland transport cost from the selected container terminals in the selected ports in Europe, the United States, and China. The generalized costs of three different transportation options (road, rail, and inland waterways) are calculated. Therefore, with this model, it is also possible to calculate the cost of purely land-based flows using, for instance, rail.

An important element of the generalized cost is the transport time. The transport time for the entire transport chain is therefore incorporated in the model. This means that the transport time from a hinterland region (including a dwell time at an inland terminal for rail or inland waterway transport) to a port, the dwell time of a container at a deep-sea port, the maritime transport, and the port and land transport times at the destination hinterland are taken into account.

The model version developed for this paper builds on the version of van Hassel et al. (2016a) and includes extensions and more detail in particular for the cost structures, elements, and values applicable to the non-European countries on the considered rail link between China and Europe. First of all, the Russian situation is introduced with more detail. Russian authorities use two different methodologies to calculate the rail tariffs for rail transporters: one for transit traffic, and one for none-transit traffic. In this paper, obviously, we are interested in transit traffic, given the China−Europe focus. The tariffs for transit traffic are set according to the "International Railway Tariff" guidelines. A number of parameters apply: nature of the commodities, number of used carriages, own or leased carriage, etc. The tariff is composed of three main components: infrastructure usage charges, traction charges, and use of leased freight wagons (if applicable). Hence, in case of own operations, one should deduct from the tariff the applicable wagon rental charges.

In the study by van Hassel et al. (2020), the first complete chain cost calculations were made for transport between the United States and Europe. These calculations include the hinterland transport on both sides of the chain both in the United States and in Europe. In this chapter, the same approach and the corresponding relevant cost values for maritime and land transport are used, but now also the Chinese hinterland is incorporated in a similar way. For the development of the road transport cost in China, a study by Wang et al. (2011) is used.

The cost function to determine the generalized road hinterland cost, for product type $i$, in China is as follows:

$$C_{R,i}^{CN} = \left(C_{Driver} + C^{FIXED}\right)^{*} TT_{Road} + (C_{Toll} + C_{Fuel})^{*} D_{Road} + C_{i}^{Cargo} * TT_{Road} \tag{9.1}$$

where $C_{Driver}$ is the cost of the driver of a truck (USD/h), $C^{FIXED}$ is the fixed cost per hour (USD/h), $TT_{Road}$ is the transport time for road transport in China (hour), $C_{Toll}$ is the toll cost per km, $C_{Fuel}$ is the fuel cost per km, and $C_{i}^{Cargo}$ is the cargo dependent value of time.

The data used for the Chinese road hinterland cost is taken from the German Chamber of Commerce in China (2017).[4] An additional element with respect to the road cost in China is that there are no mandatory driver resting times. Therefore, in the cost calculations, it is assumed that in China, only two drivers are needed per 24 h (Lau, 2018; Wang et al., 2011). With respect to inland waterway transport, no good data was found. On top of that, Seo et al. (2017) show that the total transport time via inland waterway transport from Chongqing to Shanghai can take up to 15 days. Because of this long transport time, inland waterway transport in China is mostly used for bulk transport. Furthermore, the modal share of inland waterway transport is very low. Guo and Yang (2017) state that the share is only 1%. With respect to rail transport in China, it is very difficult to have a detailed general cost function for the whole country, as each Chinese province has a different rail cost structure, added on with a heavy subsidy scheme, partly originating from the central Chinese level, and partly from individual provinces and cities. Therefore an average cost of USD 0.65/km/FEU will be used. For container handling, the cost is set at USD 44/FEU (Besharati et al., 2017; Guo and Yang, 2017; Monios & Wang, 2013; Seo et al., 2017).[5]

Based on the above information, the following cost function for rail transport can be determined:

$$C_{T,i}^{CN} = 0.65^{*} D_{Rail} + C_{i}^{Cargo} * TT_{Rail} + C_{H}^{CN} \tag{9.2}$$

4. This source has the advantage that it has processed official data sources from different origins, and made them more comparable and aligned. The original data sources often refer to different base years, case selections and calculation assumptions.

5. This value was also checked with a Eurasian rail operator and it was found that it was a realistic value (Pottharst, personal communication, 12/05/2018).

In this formula, $C_{T,i}^{CN}$ is the out-of-pocket cost for rail transport in China, $D_{Rail}$ is the rail distance, $TT_{Rail}$ is the transport time for rail transport in China, and $C_H^{CN}$ is the inland terminal handling cost. The model uses concrete distances of the existing infrastructure configuration and is able to be "disaggregate" as far as road and rail distances along a transport chain are used.

Shi et al. (2014) indicate that 9% of the total hinterland transport in China is rail transport and 91% is road transport. Therefore the aggregated hinterland cost in China can be estimated with the following function:

$$C_{HL,i}^{CN} = 9\%^* C_{T,i}^{CN} + 91\%^* C_{R,i}^{CN} \tag{9.3}$$

With respect to the cargo cost, the following additions were made to the model. First, the inventory cost of cargo type i being in transit ($C_{Invertory,\mathrm{i}}$) is being determined by the following formula:

$$C_{Inventory,i} = \frac{D_{rate,i} + V_i^{Cargo*}}{365} TTT \tag{9.4}$$

where $D_{rate,i}$ is the deprecation rate of cargo type i (percentage per year), $V_i^{Cargo}$ is the value of the cargo shipped (USD/cont), and TTT is the total transit time (days). Table 9.3 contains the cargo value data for cargo types going from China to Europa and from Europe to China.

**TABLE 9.3** Cargo value data.

| | EU to China | China to EU |
|---|---|---|
| | USD/FEU | USD/FEU |
| Capital equipment and machinery | 91,302 | 64,920 |
| Chemical products | 65,137 | 52,619 |
| Consumer fashion goods | 269,071 | 72,845 |
| Consumer personal and household goods | 43,497 | 20,862 |
| High-tech products | 333,451 | 147,785 |
| Land vehicles and parts | 62,721 | 46,867 |
| Machinery and parts | 99,630 | 54,335 |
| Raw materials, industrial consumables, and foods | 21,119 | 28,642 |
| Pharmaceuticals | 22,612 | 37,836 |

*EU*, European Union.
*Source*: Adapted from Damadoran (2018); and Hurkmans, A., 2018. Cargo value data from the port of Antwerp.

Besides the Chinese hinterland modes, additional four relevant Chinese ports are incorporated in the model: Shanghai, Ningbo, Dalian, and Yantian. These ports are added to the model because they could potentially be used as part of the considered maritime transport chains between Asia and Europe. For these ports, the port dues, pilotage cost, tug boat cost, and handling cost are collected and added to the model.

## 6. Calculation results and comparison of the selected routes

In this section, three different analyses are made. In the first one, the total generalized chain cost from six different Chinese origins to one European destination (Lodz, Poland) via the Alashankou/Khorgos land route and three maritime routes (via a southern European port, a Hamburg–Le Havre range port and Gdansk) are calculated. The selection of Lodz is, first of all, motivated by the very important role it got since the beginning of the BRI plans (Bartosiewicz and Szterlik, 2018). Furthermore, Poland is the seventh biggest importer from China among all 28 European countries in value (Eurostat, 2019). In the percentage of their total imports, Poland is even the third biggest European importer, with China representing more than 26% of its total imports.

The purpose of this analysis is to illustrate the impact of the location of the origin in China on the route choice, that is, the route with the lowest generalized chain cost. Second, an analysis will be made in which three different destinations in Europe are considered (Lodz, Duisburg, and Munich) and how this affects the route choice. Munich and Duisburg are selected because they represent the most important European consumption regions respectively arrival location of BRI rail connections. Moreover, Germany is the second largest European importer from China (Eurostat, 2019). The third analysis focuses on one specific route (Chongqing–Duisburg) but considers three cases: the impact of using reefer containers because of the harsh temperatures on the land route in either the winter or summer, the impact of having a backhaul, and the impact of the value of the cargo.

### 6.1 Impact of the location of the Chinese region of origin on the route choice

In the first analysis, the total generalized chain costs are calculated for six different Chinese regions [Xinjiang Uygur (Urumqi, 1), Liaoning (Yiwu, 2), Chongqing (3), Sichuan (Chengdu, 4), Heilongjiang (Harbin, 5), and Zhejing (Shenyang, 6)] with a destination in Europe (Lodz, Poland) for three maritime routes and a land bridge:

- Chinese region to a Chinese port and via Polish port (Gdansk) to Lodz;
- Chinese region to a Chinese port and via Southern European port (Koper) to Lodz;

– Chinese region to a Chinese port and via the HLH port (Rotterdam) to Lodz;
– Chinese region via the Alashankou/Korgos land bridge to Lodz (route 1 form Table 9.2) or via the Manzhouli to Lodz (route 2 form Table 9.2).

The calculations are made for different cargo types. The results of the calculations for Xinjiang Uygur (main city of Urumqi) can be seen in Table 9.4.

From Table 9.4, it can be concluded that the total generalized chain costs are the lowest for the land bridge for all product types. The cost of the maritime route via Gdansk is always the lowest for all three considered maritime routes. This is mainly because of the geographical location of Lodz, close to the port of Gdansk.

For the five other Chinese regions, the same calculations are made. The results are plotted in the maps in Fig. 9.8. For the regions of Heilongjiang (Harbin, 5) and Zhejing (Shenyang, 6), the Manzhouli land bridge is used instead of the Alshnakou/Khorgos one. There is a map for household goods and one for high-tech products. In these maps, two colors are used—red denotes that the land route has the lowest generalized costs, whereas blue

**TABLE 9.4** **Total generalized chain cost for transporting an FEU container from Xinjiang Uygur to Lodz (USD/FEU).**

| Product type | Route | | | |
|---|---|---|---|---|
| | Maritime | | | Land bridge |
| | Gdansk | Koper | Rotterdam | Alashankou/ Khorgos |
| Capital equipment and machinery | 8494 | 8969 | 9742 | 4647 |
| Chemical products | 7733 | 8285 | 8752 | 4439 |
| Consumer fashion goods | 8461 | 8941 | 9442 | 4638 |
| Consumer personal and household goods | 6766 | 7031 | 7435 | 4058 |
| High-tech products | 12,982 | 14,100 | 14,864 | 6206 |
| Land vehicles and parts | 7636 | 8020 | 8474 | 4358 |
| Machinery and parts | 7904 | 8325 | 8795 | 4451 |
| Raw materials, industrial consumables, and foods | 6983 | 7277 | 7693 | 4133 |
| Pharmaceutical goods | 7886 | 8304 | 8773 | 4445 |

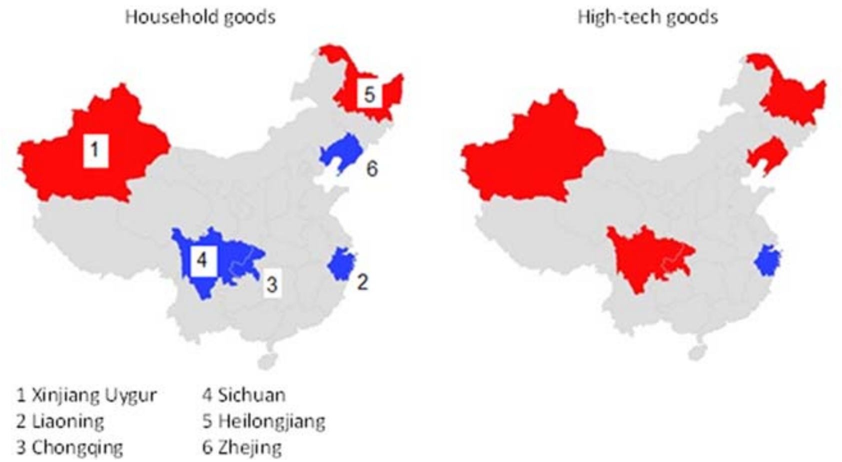


**FIGURE 9.8** Generalized chain cost comparison between Chinese hinterland regions and Lodz (EU) (left = household goods and right = high-tech equipment).

denotes that one of the maritime routes has the lowest generalized chain cost.

Based on the results of Fig. 9.8, the following observations can be made. First, Chinese regions that are more inland located will have lower generalized chain costs when using the land bridge, whereas for the regions located closer to the main Chinese ports, use will be made for the maritime route will be used. Another important observation can be made regarding the impact of the value of the cargo. For high-tech cargo (higher value of the cargo, which means a higher opportunity cost during transport), more use will be made of the land bridge, then for household goods, which have a lower opportunity cost during transport. This is also observed in reality, where HP is using the land bridge from Chongqing to Europe for shipment of their computers to the European market.

## 6.2 Impact of different European regions on the route choice

For the second analysis, the generalized chain costs are calculated for chains going from Chongqing to Duisburg, Munich, and Lodz. The results can be seen in Fig. 9.9. The calculations are again done for household goods and high-tech goods.

In Fig. 9.9, it can be seen that for household goods, a maritime route via Rotterdam (Duisburg), Koper (Munich), and Gdansk (Lodz) has lower generalized chain costs than the land bridge. For high-tech goods,

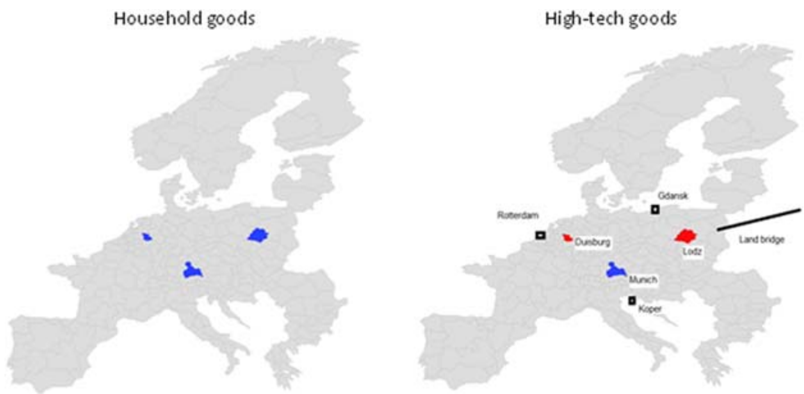


**FIGURE 9.9** Generalized chain cost comparison between European hinterland regions and Chongqing (China; left = household goods and right = high-tech equipment).

the picture is different. For Duisburg and Lodz, the land bridge is a better alternative (lower generalized chain cost) than the maritime routes. For Munich, the maritime route via Koper has the lowest generalized chain cost.

## 6.3 Sensitivity analysis of the obtained results

There are some elements in the analysis that deserve some further attention:

- The impact of using reefer containers to protect the cargo during the harsh condition while using the land bridge.
- The impact of having a backhaul for the land bridge.
- An increase in the value of the cargo shipped from China to Europe.

The calculations are made for the transport chain from Chongqing to Duisburg.

## 6.4 The impact of using reefer container

In Fig. 9.10, the results of the calculations are shown when reefer containers are used to keep the temperature at a constant level for certain cargo types.

If the costs for using a reefer container are taken into account, it can be observed that the generalized cost of the land bridge will increase, so making it less attractive. For high-tech goods, the land bridge is still a suitable alternative for the maritime route although the cost difference is becoming very small.

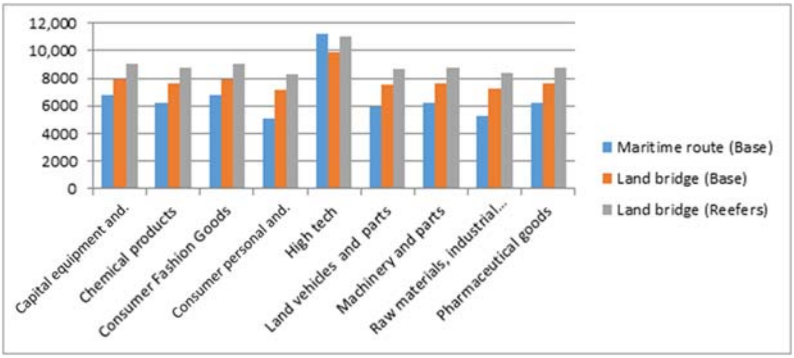


**FIGURE 9.10** Impact of using reefer containers on the cost of the land bridge route (Chongqing–Duisburg; USD/FEU).

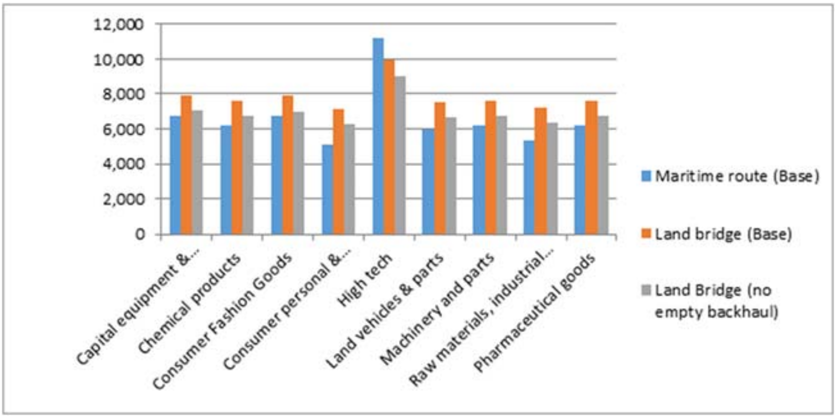


**FIGURE 9.11** Impact having a backhaul on the land bridge (Chongqing–Duisburg; USD/FEU).

## 6.5 The impact of having a backhaul

The results of the calculation of having a backhaul and not having to include the cost of an empty backhaul can be seen in Fig. 9.11. This situation can occur when trade volumes between China and Europe are more in balance.

Having a backhaul implies that the cost of the land bridge are decreased. This makes that the land bridge becomes more attractive. For the transport link between Chongqing and Duisburg, it can even be seen that for capital equipment, machinery, and consumer fashion goods the cost difference between the maritime route and the land bridge is becoming very small. So if the trade balance between China and Europe is more balanced, that is, also cargo will be shipped from Europe to China, more cargo types can be transported via the land bridge.

## 6.6 The impact of an increase in the value of cargo shipped from China to Europe

Fig. 9.12 shows the results of the generalized chain cost calculations if it is assumed that in the future, the value of the goods shipped from China to Europe will be the same as the value of the cargo from Europe to China. This situation can occur when the labor cost in China continues to rise.

From the obtained results, it can be concluded that for certain cargo types, such as consumer fashion goods and high-tech goods, increasing the level of the value of the goods shipped from China to Europe makes the land bridge more attractive than the maritime route. For other cargo types, such as machinery and parts and capital equipment, the difference in generalized chain cost between the land bridge and the maritime route is reduced. This makes that the land bridge is increasing its competitiveness toward the maritime route. For other cargo types, such as household goods, increasing their value has hardly any noticeable impact.

The sensitivity analysis shows that the obtained results in Sections 10.6.1 and 10.6.2 depend on factors such as using a reefer container to protect the cargo, the trade balance between Europe and China, and the cargo value. Generally, it can be concluded that if the Chinese economy is transforming to one in which more high-end products are produced and consumed, then both the value of the cargo is increasing and the trade balance between China and Europe is more balanced. This situation will make, for some cargo types, the land route more attractive. However, if reefer containers are needed on the land route, its competitiveness with the maritime routes will decrease.

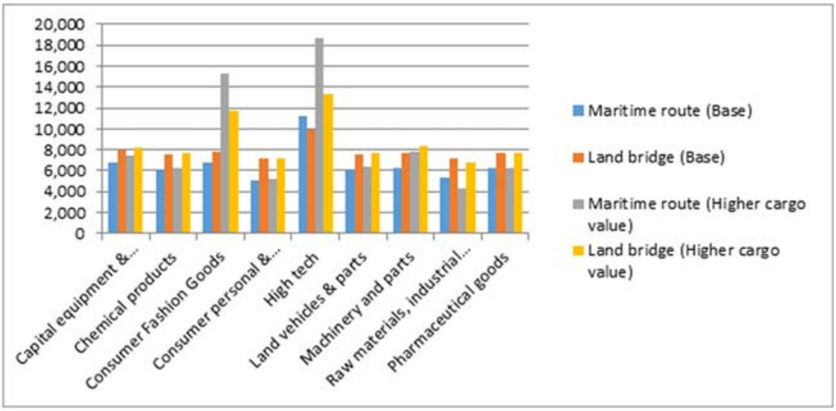


**FIGURE 9.12** Impact of using European Union cargo values for shipments between China and Europe (Chongqing–Duisburg; USD/FEU).

## 7. Conclusions

This chapter dealt with the potential of an all-rail based solution on the China–Europe connection as an alternative for the traditional maritime route and the land–sea route. The focus is on the generalized costs, as they are the basis for the pricing strategies of the operators on the routes. The BRI, as the main driver, is the starting point for the specification of the corridors and the scenarios to be considered. Equally, the barriers to the BRI path were identified. With that information, a number of scenarios of future rail development on the connection were derived, which were the basis for the calculation of the route-generalized costs.

The attractiveness of the land bridge depends on several factors. First of all, there is the geographical location of the origin and destination of the transport chain. Second, there is the effect of the different types of cargo. It can be concluded that the lower the value of the transported cargo, the larger the catchment area of the maritime routes between China and Europe. In this case, only transport chains from the West of China to the Eastern regions of Europe (regions that are relatively far away from the major container ports) have a potential for using the land bridge. However, if the value of the cargo increases, the catchment area of the land bridge becomes larger. This is also observed in reality where HP is shipping high-end products from Chongqing to Duisburg for distribution in large part of Europe.

The obtained results of the generalized cost calculations depend on factors such as using a reefer container to protect the cargo, the trade balance between Europe and China, and the cargo value. Generally, it can be concluded that if the Chinese economy is transforming to one in which more high-end products are produced and consumed, then both the value of the cargo is increasing and the trade balance between China and Europe is more balanced. We see this evolution already when looking at trade statistics: vehicles, equipment, and other manufactured goods are among the strongest growers in trade value. These situations will make, for some cargo types, the land route more attractive. However, if reefer containers are needed on the land route, the attractiveness of the land route will decrease.

Although the generalized costs will have an impact on the success or failure of a land route, other factors can be decisive. Market power and pricing strategies in the maritime sector can affect the pricing and profitability of the operators of the land route. Of course, also pricing in rail will have an impact: if China reduces its subsidies for rail traffic to Europe, rail prices will inevitably have to rise, making the rail corridor a less interesting option for many regions. Furthermore, geopolitical factors can make the land bridge less reliable than the maritime route. This means that only if the land bridge can offer a reliable transport service, it can be an alternative, for certain cargo types and trade relations, for the current day maritime transport chains. At the same time, European countries may use the BRI and its Chinese political linkage as a means to increase pressure on the European Commission to obtain more subsidies or other advantages. It would, therefore, be relevant to further study and quantify the above impacts.

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Chapter 10

# Freight modeling and policy analysis for megacities: the case of New Delhi

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## Highlights

- A freight travel demand model developed for the urban road network of Delhi.
- Evaluates appropriate freight transport related scenarios for the improvement of the traffic conditions of the urban road network.
- The introduction of electric freight vehicles shows promising results in emissions reduction.

## 1. Introduction

The Indian freight transport market is expected to grow at a compound annual growth rate of about 13% by 2020 driven by the growth in the manufacturing, retail, fast-moving consumer goods, or consumer packaged goods, and e-commerce sectors have large freight transport requirements across the country, which is generally done by road transportation. In India, road freight constitutes around 63% of the total freight movement consisting of 2.2 million heavy-duty trucks and 0.6 million light-duty trucks, covering more than 1.8 million km of road length, carrying more than 3000 MMT of load annually (Novonous, 2015). Owing to poor road conditions and checkpost delays, trucks in India travel for 20 days a month on an average compared with 25 days in developing countries. The delays could range from 5% of time taken in a journey to a high of 25%. The average speed of trucks on Indian

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roads is about 20 km/h, and a truck in India can cover only 250–300 km a day compared with 700–800 km in developed countries such as the United States and Europe (TCI-IIMC, 2009). The comparison of these characteristics of India with other developed countries, namely, the United States and the European Union, is presented in Table 10.1. Moreover, on an average, total trip expenses increase about 15% because of the delays at checkposts and on road for filling in forms required by various government departments, checking of documents and physical checking of the vehicles, drivers, and consignments by regional transport offices and traffic police, and collecting highway toll and taxes (TCI-IIMC, 2016). The working conditions for the truck drivers are also deteriorating as they work for long hours, resulting in high stress and fatigue, which leads to accidents. There is increasing recognition in India that transport infrastructure could become a serious bottleneck for future economic growth. The need is recognized for collaboration among stakeholders to identify optimal policies and pursue a rapid deployment of improvements.

The present paper considers the Delhi urban road network as object of study. As per the Census (2011), Delhi has 16.75 million population, which recorded a decennial population growth of about 20%. The increase in urbanization leads to the growth of vehicular population in urban areas, and this scenario accelerates various traffic problems such as congestion, air pollution, and reduction in safety. There is significant momentum in government to consider the city logistics system as a sustainable development priority. A recent verdict by the National Green Tribunal of India banned the entrance of trucks older than 10 years to the city of Delhi in view of high pollution emission by these vehicles. To study and understand these issues, new policies are required, and innovation needs to be promoted. The roads of Delhi have number of time restrictions for goods vehicles, and there is 24-hour ban for some

**TABLE 10.1 Freight (trucks) vehicle characteristics in India and the United States/European Union.**

| Parameter | USA/EU | India |
|---|---|---|
| Average distance traveled in a day | 700–800 km | 250–300 km |
| Average truck speed | 53 mph (90 kmph)[a] | 20 kmph |
| Average days of travel in a month | 25 days | 20 days |

[a] *FHWA (2010)*.

roads. The restriction is from 7:00 to 11:00 a.m. and 5:00 to 11:00 p.m. for most of the roads in Delhi.

Delhi is known as one of the most air-polluted cities in the world as the air quality index (AQI) of most areas is above 150 (Delhi Air Pollution: Real-time Air Quality Index, 2017). AQI from 0 to 100 is in range of good to moderate. AQI more than 150 is considered unhealthy (Air Now, 2017). Emission from motor vehicles is one of the major reasons for poor air quality in Delhi. The traffic congestion on Delhi road is as intimidating as the polluted air. It was revealed from the present study that more than 100,000 freight vehicles daily crossed 10 count stations at the borders of Delhi. Clearly, freight transportation has its fair share of the pollution and congestion in Delhi. The average share of freight vehicles in Delhi is relatively low overall. However, because of time window restrictions by local authorities, the share of freight vehicles varies during different times of the day and night. For instance, certain types of freight activities (e.g., furniture delivery, milk van, etc.) are allowed between 8:00 a.m. and 4:00 p.m. During that time, the share of freight vehicle increases by 15%–20%. From midnight 12:00 a.m. onwards, all freight vehicles are allowed in the city, which leads to high traffic volumes of freight vehicles on the road network. The light commercial vehicles, trucks, and goods auto-rickshaws form the backbone of urban freight movement in Delhi for long and medium distances. For short distances, nonmotorized vehicles (e.g., animal cart, hand cart, head load, and cycle rickshaw) are extensively used, especially in the highly congested parts of the Delhi (Gupta, 2017). Another interesting fact is that with online shopping spree, companies use motorized two-wheeler trips as a mode to navigate the high density and congestion of Delhi (De-Bakshi et al., 2017).

Understanding and forecasting freight movements are critical to plan for future transportation in terms of capacity increase, operation, preservation, safety and security, energy, and economy investment needs. Many demand forecasting models and data sources are more appropriate for passenger transportation than for forecasting freight movements and understanding freight travel behavior. Creating better data and models is needed to enable planners to better predict freight movement and design better informed policies. In view of this, a consortium of the Council of Scientific and Industrial Research-Central Road Research Institute (CSIR-CRRI), the Toegepast Natuurwetenschappelijk Onderzoek (TNO; English: Netherlands Organisation for Applied Scientific Research), and the Delft University of Technology (TU-Delft) carried out a study for the World Bank Group under the Multi-Donor Trust Fund-Sustainable Logistics Scheme. In this chapter, the major freight modeling development effort carried out for Delhi City has been reported (CRRI et al., 2018).

The chapter is composed of six sections: Section 10.2 explains the methodology adopted to develop the freight demand model, and Section 10.3 introduces the available traffic and fleet data for freight modeling. Section 10.4 introduces the freight modeling, and Section 10.5 presents the application of the developed freight model. The conclusions that emerged out of this study have been discussed in Section 10.6.

## 2. Methodology

To develop a freight demand model and evaluate suitable freight transport policies, an appropriate methodology has been conceptualized into the present study, which is presented in Fig. 10.1. From the Fig. 10.1, it can be seen that the understanding the freight-related problem and selection of the study area have been done in the first step, and subsequently, the data collection step has been carried out by conducting appropriate traffic surveys. The details of the data collected from various traffic surveys have been discussed in the next section. The collected data have

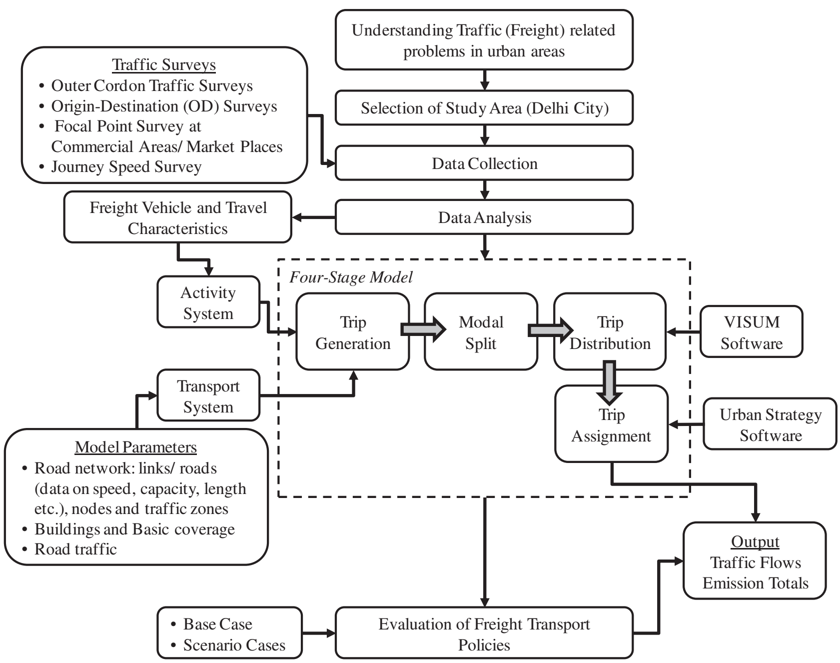


**FIGURE 10.1** Methodology adopted in the development of freight demand model in the present study.

been analyzed to assess the freight vehicular characteristics as well as travel characteristics of freight in the study area. These characteristics have been used in forming input to develop four-stage model (FSM) through activity system. The procedure to develop a four-stage freight demand model was followed as per the study of McNally (2008). The FSM provides a mechanism to determine equilibrium flows, as illustrated in Fig. 10.1. The FSM was developed to deal with this complexity by formulating the process as a sequential four-step model. First, in trip generation, measures of trip frequency are developed providing the propensity to travel. Trips are represented as trip ends, productions, and attractions, which are estimated separately. Next, in modal split, trips are essentially factored to reflect relative proportions of trips by alternative modes. Next, in trip distribution, trip productions are distributed to match the trip attraction and to reflect underlying travel impedance (time and/or cost). Finally, in trip assignment, modal trip matrices/tables are assigned to different routes to mode-specific networks, thus forming the link flows for the entire network.

In the present study, the static FSM has been adopted because of the data and other resource constraints. As the data were accumulated for the entire day, the peak hour—based analysis also could not be carried out in the present study. For the trip generation stage, the multiple linear regression (MLR) methodology has been implemented. In the case of trip distribution, the VISUM software has been used and estimated the parameters of gravity model through the iteration process. The modal split stage basically dividing the trips based on the mode shares and the share is taken directly from the observed data and could not develop any choice mode choice model because of data constraints. The trip assignment stage has been performed in Urban Strategy Software using user equilibrium method and assigned all the links flows for both passenger and freight trips. After developing the four-stage freight demand model, the scenarios-related freight traffic has been conceptualized for evaluation purpose. The scenarios mainly considered from the discussions with stakeholders in the workshop and also based on prevailing air quality and traffic conditions in the study area. Finally, these scenarios have been evaluated based on the outputs of the model, namely, traffic flows and emission totals of various particles.

## 3. Traffic and fleet data

For the purpose of modeling, a database needed to be created by collecting freight travel behavior data, road network, economic data, etc.

## 3.1 Traffic surveys

The following traffic surveys have been undertaken:

1. Outer cordon traffic surveys—at 10 locations

   *These surveys were conducted to estimate the quantum of traffic entering or exiting the city of Delhi and the share of freight traffic.*
2. Origin-destination (OD) surveys at outer cordons—10 locations

   *These interview surveys were conducted to collect the freight vehicle and travel characteristics of freight traffic entering or exiting the city of Delhi so as to develop the OD matrix.*
3. Focal point surveys at commercial areas/market places—20 locations

   *These interview surveys were conducted to collect the freight vehicle and travel characteristics of freight traffic plying within Delhi so as to develop OD matrix.*
4. Journey speed survey on arterial road network—for a road length of 418 km

   *This survey was conducted to collect the journey speed, which would be used in making road network and skim matrix for developing travel demand model for freight traffic.*

### 3.1.1 Outer cordon surveys

By analyzing the roadside interview data collected at the selected 10 outer cordon locations, overall pattern of external traffic in the city on a normal working day along with their composition was estimated. The results reveal that a total of about 1.24 million vehicles enter and leave Delhi city on normal working day, which was about 1.02 million vehicles in 2009 (CRRI, 2009). From this result, it can be observed that the external traffic has grown with 3% per annum. It can also be noticed that the goods traffic forms about 10% of the total traffic, with another 4% of traffic is composed of slow-moving vehicles such as bicycles and animal carts. The pattern of external freight traffic in the city on a normal working day along with their composition was estimated and shown in Fig. 10.2. The results reveal that a total of about 100,000 freight vehicles enter and leave Delhi city on normal working day, and about 21% of these freight vehicles are found to be passing through the city, which was almost the same in 2009 (CRRI, 2009).

From these results, it can be observed that although the total traffic increased, freight traffic remain stagnated at outer cordons because of new bypass roads in the recent past come around the city of Delhi such as Noida−Greater Noida Expressway, Yamuna Expressway, and Kundli−Manesar−Palwal Expressway. It can also be observed that the vehicle types, namely, goods auto (GA) and goods van (GV), light truck (LT), heavy truck (HT), and multiaxle truck (MT) have almost equal share about

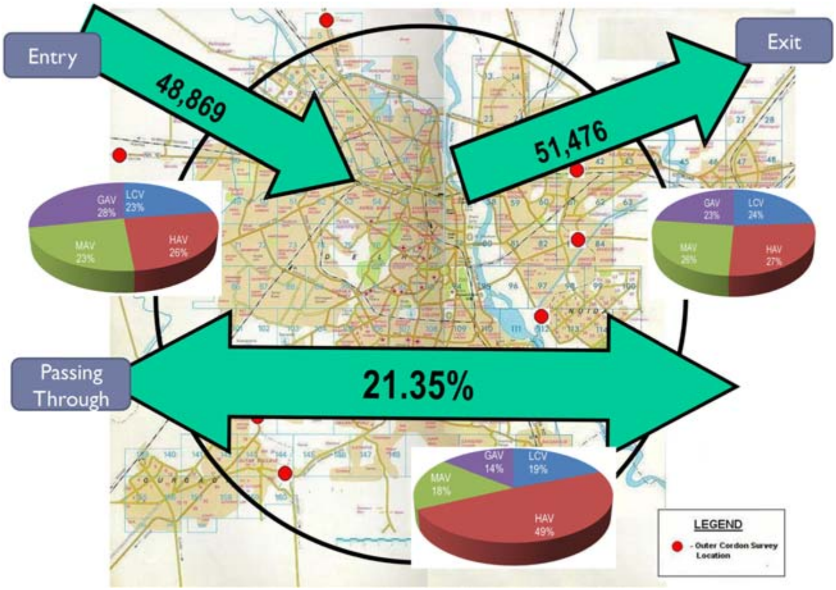


**FIGURE 10.2** Pattern of freight external traffic at outer cordons of Delhi. *LCV*, light commercial vehicles.

25% at entry and exit locations of outer cordons. In the case of passing through traffic, HT has almost 50% share followed by MT, and LT has a share of about 18% each. Smaller goods vehicles (GA and GV) have a share of about 14% of passing through traffic. This can be attributed to the fact that heavy vehicles travel long distances compared with light and small vehicles.

### 3.1.2 *Focal point surveys*

By analyzing the interview data collected at selected 20 focal points of market/commercial places, the freight vehicle and travel characteristics of internal freight traffic in the city on a normal working day along with their composition were estimated. The results revealed that maximum number of vehicles per day of about 8000 entering and exiting through Ghanta Ghar Sabzi Mandi (vegetable market) followed by Azadpur Sabzi Mandi (vegetable market) with an entry/exit volume of about 7000 and Chandini Chowk Commercial Area with an entry/exit volume of about 5000. The summary of all the focal points in terms of freight traffic composition is presented in Fig. 10.3. From Fig. 10.3, it can be inferred that about 40% are consisting of GA and GV. The vehicle types of LT, HT, and MT are in the range of 24%, 11%, and 8%, respectively, and the other freight vehicles are about 18%.

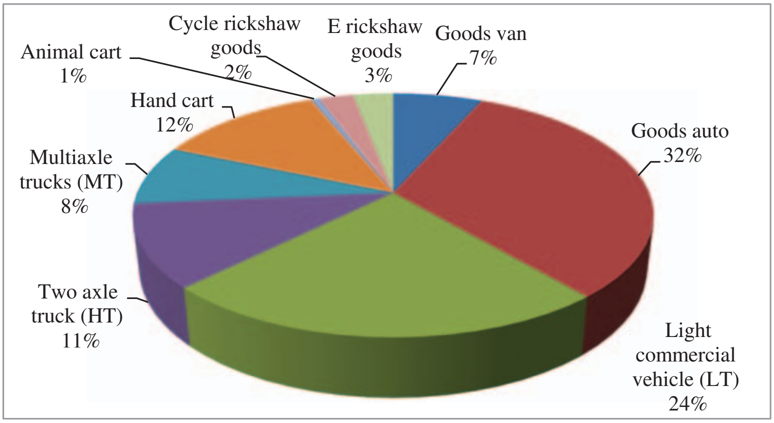


**FIGURE 10.3** Freight modal composition at different focal points of Delhi.

## 3.2 Freight vehicular and travel characteristics

A total of 8391 freight vehicles at 10 outer cordon locations and 10,091 freight vehicles at 20 focal points (within the city) were intercepted and interviewed. Through the roadside interviews, the age of the vehicles was recorded along with other important travel characteristics and analyzed for all the sampled vehicles. From the data of model (manufacturing) year of vehicle, the age of vehicle has been determined, and age distribution is developed for different freight vehicle types at outer cordons and within city. It can be found that the mean age is almost the same at outer cordons and within the city varying between 4.5 and 5.0 years, and the share of 10-year-old vehicles at outer cordons within the city is ranging from 1% to 6% and 5% to 9%, respectively.

In the case of freight vehicles, two types of fuels are mainly used: diesel and compressed natural gas (CNG). Heavy vehicles mostly use diesel, whereas GA and GV almost use CNG as fuel. In the case of LT, about 45% and 75% use diesel as fuel at outer cordons and within city, respectively.

The ownership of different freight vehicles at outer cordons and within the city has been analyzed, and it can be found that private company vehicles are high in the case of heavy vehicles (HT and MT) at outer cordons and within the city. The private vehicle share is almost the same for light vehicles (LT, GA, and GV) within the city, whereas it is higher at outer cordons.

The mileage (fuel efficiency in terms of kilometer/liter) data of different freight vehicles have been analyzed, and it can be found that light vehicles (LT, GA, and GV) have higher fuel efficiency, which are mostly run on CNG. Heavy freight vehicles have average fuel efficiency of about 6.5 and 4.8 km/L for HT and MT, respectively. Light vehicles, namely, LT, have about 11 km/L, whereas GA and GV have more than 14 km/L.

The distance traveled data in terms of km/trip, km inside the city, and km/day of different freight vehicles have been analyzed. The average trip distance of MT is about 228 km, and for HT, it is about 112 km, whereas LT has about 70 km, and smaller vehicles are having a trip distance of about 50 km. All these vehicle types travel about 20−25 km within the city. And it can also be observed that the maximum average daily distance traveled by these vehicle types is about 200 km. This clearly indicates that freight vehicles face a lot of congestion and other problems to travel longer distances in a day experiencing lot of delays and increased operating costs.

The frequency of trips data of different freight vehicles have been analyzed. It can be observed that light vehicles are having more daily trips, and heavy vehicles are more on occasional trips. In terms of weight carried, it can be observed that MT vehicles are carrying more than 13 tons, whereas HT vehicle is carrying loads of 5−6 ton. The LT is carrying about 2 ton, and smaller vehicles such as GA and GV are carrying less than a ton. Furthermore, an analysis has been carried out to assess the share of empty vehicles and found that about 10%−20% of vehicles are running empty on the road network of Delhi. Furthermore, the total weight carried by these freight vehicles on the entire road network of Delhi has been estimated from average distance traveled and weight carried in a day, which comes to be about 2.480 MMT per day.

## 4. Freight demand models

### 4.1 Background

Generally, passenger transport models are developed based on the observed travel pattern and the socioeconomic characteristics of commuters of the city. The traditional approach of four-stage modeling has the following transport submodels: (1) trip generation, (2) trip distribution, (3) modal split, and (4) traffic assignment. In the present study, the freight transport demand model has been proposed to develop considering the same traditional approach of four-stage modeling based on trips. Accordingly, freight trip generation and freight trip distribution models have been considered. The freight modal split has been estimated from observed data, and freight OD matrices are determined from generation and distribution models. Using these OD matrices, freight traffic assignment along with passenger traffic assignment has been carried out. Before this, the development of the existing transport network is the foremost data input for the transport models besides the observed travel characteristic data and planning parameters at the traffic zone level, which are discussed in the next sections.

### 4.2 Traffic zones, road network, and socioeconomic data

The study area, that is, the National Capital Territory (NCT) of Delhi, is divided into 360 administrative wards, and the same has been adopted in the present study. The zone-wise socioeconomic data such as population, land use types, number of households, employment, total land in hectares, commercial area, industrial area, residential area, recreational area, public and semi-public area, etc., which are going to be used for the development of travel demand modeling, are also collected from the secondary source, namely, Census data (Census, 2011) and Master Plan for Delhi—2021 (DDA, 2010). The traffic analysis zone (TAZ) centroids have been serially numbered starting from 1 onward for each of the TAZ of the NCT of Delhi (1−360) and also considering external zones (361−368), as shown in Fig. 10.4. The transport network has been prepared for the whole of NCT of Delhi area including external zones. The road network of study area, that is, NCT of Delhi, has been created from the existing maps and field visits. The

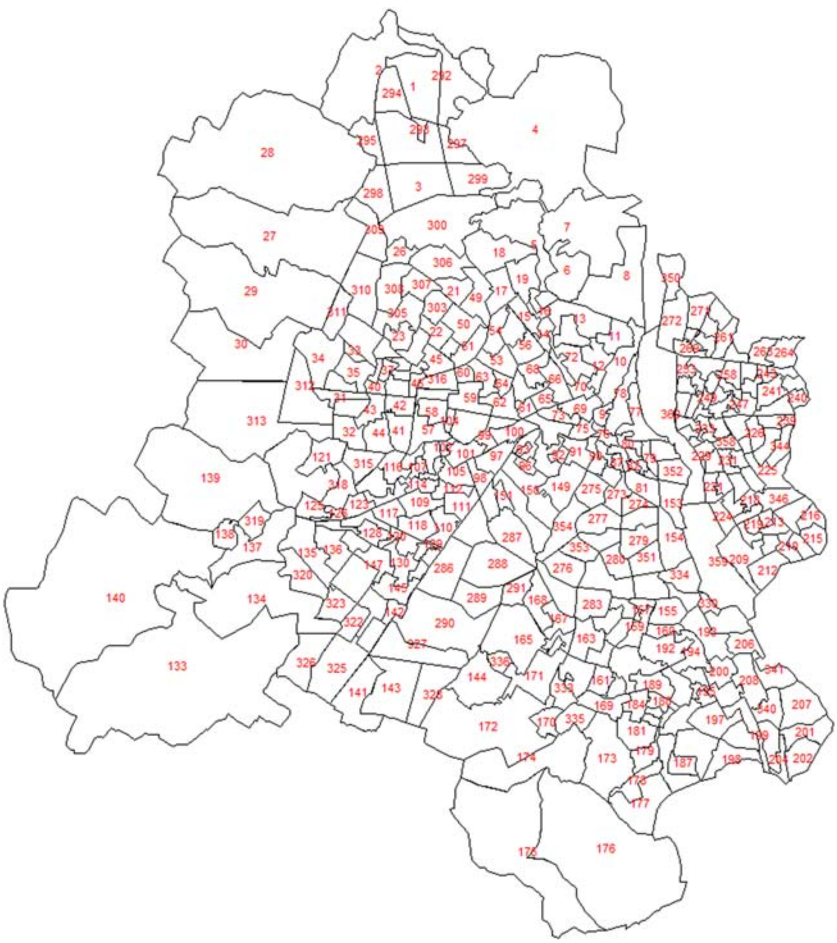

**FIGURE 10.4** Traffic analysis zones (TAZ) considered for the City of Delhi.

**FIGURE 10.5** Created road network (links and nodes) for the City of Delhi.

network has been developed by creating links and nodes, as shown in Fig. 10.5.

The existing transport network of Delhi city consists of only roads, as the road-based mode is only considered at present. The road network has a total of 2263 links and 1500 nodes and included road link characteristics are link type, length, observed carriageway width, number of lanes, divided/undivided, and speed, capacity, etc. The speeds for different links are taken from the Journey Speed Surveys and implemented separately for different types of roads, namely, major roads, intermediate roads, connectors, etc.

## 4.3 Freight trip generation models

The freight trip data have been analyzed based on zone wise and estimated the trips generated both productions and attractions from that zone. MLR technique has been used to model the freight trip productions and attractions. Of the socioeconomic and land use parameters discussed in the previous section, the following variables are taken as influential parameters in estimating freight trip productions in zonal level:

- Population (*P*)
- Employment (*E*)
- Commercial area (*C*)
- Industrial area (*I*)

Using the abovementioned variables, the zonal trip productions are modeled and developed zonal-level trip production regression models. For this purpose, SPSS 18 has been used to estimate the parameters and statistical validation. The developed equation for freight transport trip productions for zone $i$ ($PRi$) is given below:

$$PR_i = 0.021^{*}P_i + 0.003^{*}E_i + 14.499^{*}C_i - 17.858^{*}I_i \qquad (10.1)$$

The above regression equation can be considered as relatively good statistical significance, as it is having an $R^2$ of 0.3.

Similar to trip productions, MLR technique has been used to develop the equation for freight trip attractions. However, three socioeconomic and land use parameters of population ($P$), employment ($E$), and commercial area ($C$) as influential parameters have been used in estimating freight trip attractions in zonal level. Using the above variables, the zonal trip attraction models are developed. For this purpose, SPSS 18 has been used to estimate the parameters and statistical validation. The developed equation for freight trip attractions for zone $i$ ($ATi$) is given below:

$$AT_i = 0.026^{*}P_i + 0.002^{*}E_i - 17.564^{*}C_i \qquad (10.2)$$

The above regression equation can be considered as relatively good statistical significance, as it is having an $R^2$ of 0.38. From this analysis, it can be concluded that the developed equations for trip productions and attractions can be used to estimate trips with relatively good accuracy.

From the developed freight trip production and attraction models given in Eq. (10.1) and Eq. (10.2), the total trips have been estimated from all the zones and presented in Fig. 10.6. From Fig. 10.6, it can be seen that about 500,000 of freight trips are generated in terms of productions and attractions daily in the city of Delhi. The passenger trips that are estimated in the project of SUSTRANS (CRRI, 2017) for the city of Delhi have been considered, and the comparison of total freight trips is made with passenger trips to

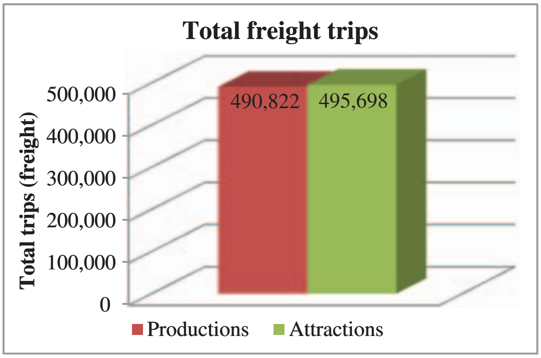


**FIGURE 10.6** Estimated total freight trip productions and attractions in Delhi.

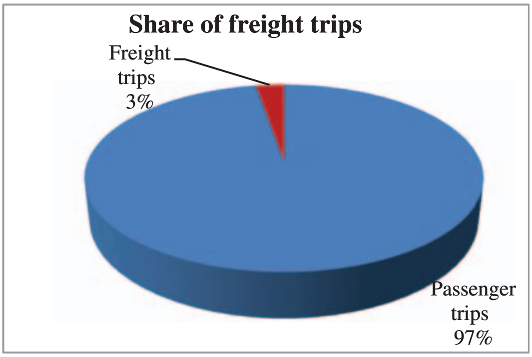


**FIGURE 10.7** Share of freight trips in the total trips of Delhi.

understand the share of freight trips in the city of Delhi and shown in Fig. 10.7. From Fig. 10.7, it can be observed that although the share of freight trips is only about 3%, which is insignificant, it greatly influences traffic congestion, air pollution, and road safety—related issues of the city of Delhi. The estimated passenger and freight trips are further used as a base for the traffic assignment stage as explained in the subsequent sections.

## 4.4 Freight modal split

In the present study, trip end modal split analysis has been carried out, which is normally performed after trip generation. Freight mode choice data could not be collected because of limited resources and time availability in the present study; hence, mode choice modeling could not be carried out because of lack of freight mode choice data. This can be considered as a limitation of the study. After estimation of the total freight trips from each of the zone, the modal split has been estimated considering the traffic composition observed at outer cordon and within the city at focal points. These trips have been analyzed based on the observed data on pattern of total freight trips, which can be classified under four categories. They are as follows:

- External to external (E-E)
- External to internal (E-I)
- Internal to external (I-E)
- Internal to internal (I-I)

Accordingly, the freight trips are analyzed, and the results are shown in Fig. 10.8. From Fig. 10.8, it can be seen that the majority of freight trips are I-I, which is almost 80%. The I-E and E-I are almost the same about 8% each, and E-E trips (passing through) are about 4%.

The modal split of these freight trips has been analyzed and presented in Fig. 10.9. From the Fig. 10.9, it can be observed that heavy freight vehicle

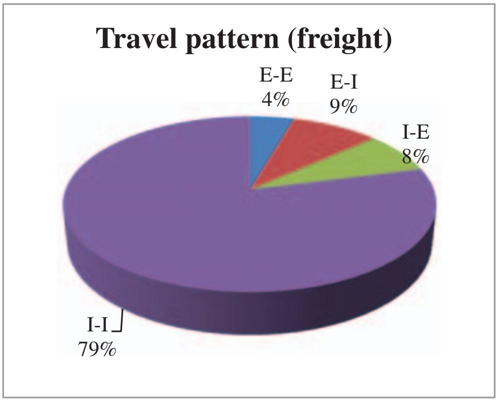


**FIGURE 10.8** Pattern of total freight trips in Delhi. *E-E*, External to external; *E-I*, external to internal; *I-E*, internal to external; *I-I*, internal to internal.

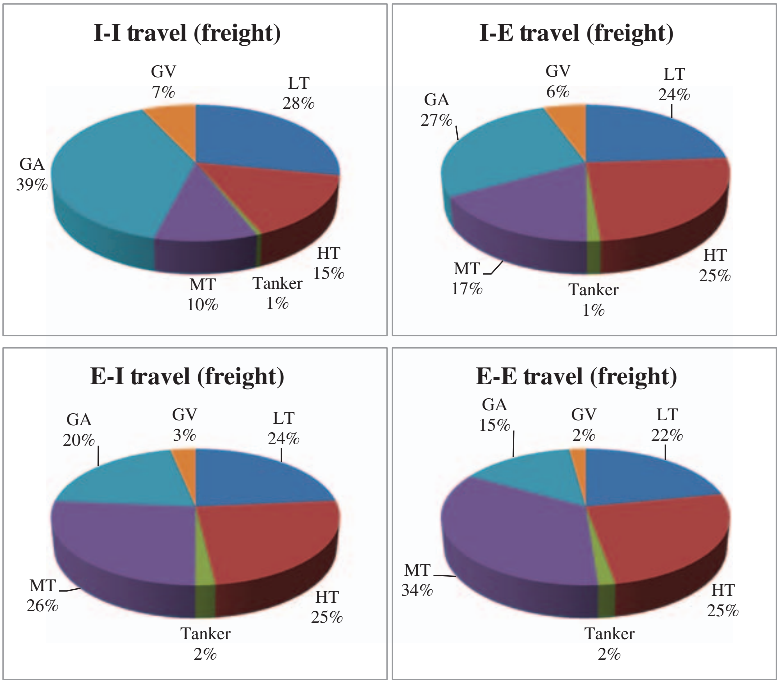


**FIGURE 10.9** Freight modal split for different types of trips in Delhi. *E-E*, External to external; *E-I*, external to internal; *GA*, goods auto; *GV*, goods van; *HT*, heavy truck; *I-E*, internal to external; *I-I*, internal to internal; *LT*, light truck; *MT*, multiaxle truck.

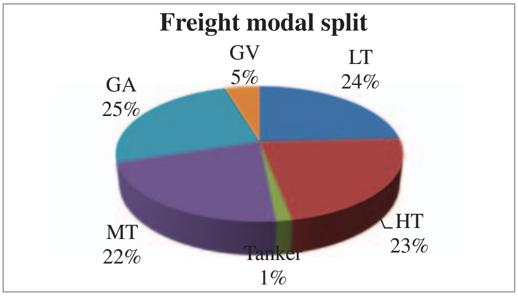


**FIGURE 10.10** Modal split of total freight trips. *GA*, Goods auto; *GV*, goods van; *HT*, heavy truck; *LT*, light truck; *MT*, multiaxle truck.

share is about 26% in case of I-I Trips, about 43% in case of I-E trips, about 53% in case of E-I trips, and about 61% in case of E-E trips.

The final estimated freight modal split by combining all the above types of trips is shown in Fig. 10.10. From Fig. 10.10, it can be observed that all different freight vehicles, namely, GA, LT, HT, and MT, form almost equal share varying between 22% and 25%, where GV is about 5% share.

## 4.5 Freight trip distribution models

In the present study, gravity model formulation has been used for trip distribution model calibration (McNally, 2008). Freight trip distribution models have been calibrated using the distance and time skim matrices generated from the coded network of existing roads. In the present study, the total number of zones taken as 368, of which 360 are internal zones and eight are external zones. The observed OD trip matrices have been separately calibrated for each mode. For this purpose, VISUM 11 software has been used and estimated freight OD matrices for different freight vehicle types. The estimated OD matrix (size is 368 × 368) for all the zones and all the freight vehicles from the developed trip distribution model in VISUM is displayed in the form of desire line diagram in Fig. 10.11.

## 4.6 Freight trip assignment

### 4.6.1 Urban Strategy platform

The trip assignment has been performed using the Urban Strategy platform. When the assignment of freight trips made on the network, there would be passenger trips already on the network. Hence, it is essential to consider all the trips including freight and passenger trips to perform trip assignment. The passenger trips that are developed in the project of SUSTRANS (CRRI, 2017) for the city of Delhi has been used as a base load for the network assignment.

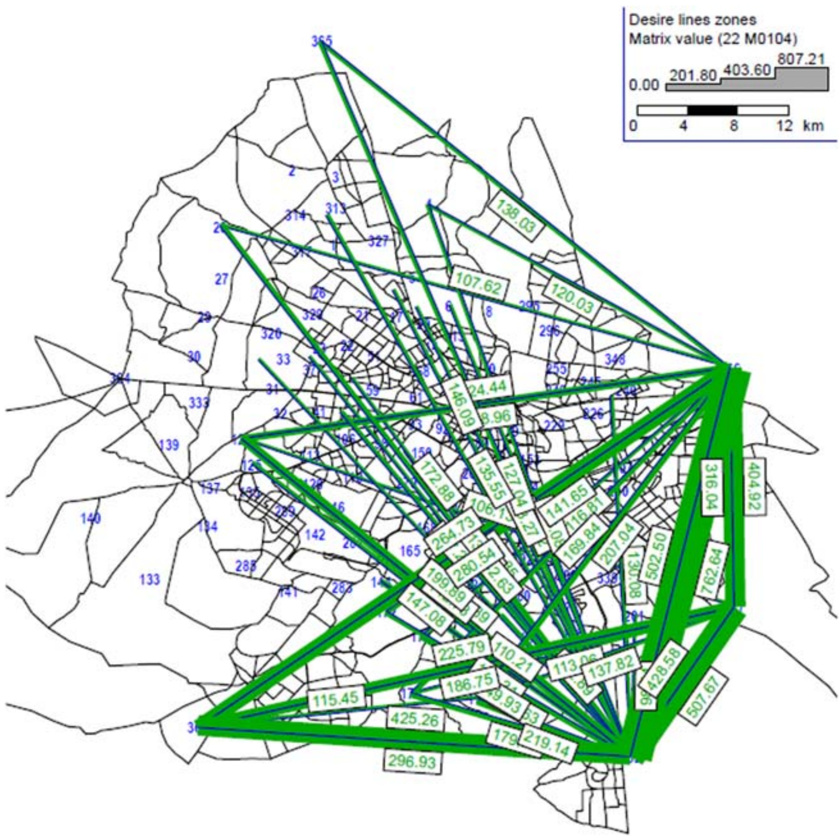


**FIGURE 10.11** Desire line diagram of OD matrices for freight trips.

Urban Strategy is a software platform developed by TNO for interactive spatial planning, in which calculation models are linked to databases. Using a set of interfaces, it is possible to gain insight into the effects of plans and measures in the time span of a workshop. Areas covered by Urban Strategy include traffic, transport, noise, air quality, safety, and sustainability. Different scenarios and measures, such as altering traffic circulation, new buildings or land use, or lowering speed limits, can be interactively explored with the system. It directly shows the updated detailed traffic calculations, air quality maps and noise contour maps, as well as indicators describing the impact (such as annoyance) after a measure has been applied through the interactive interface. Because Urban Strategy integrates different from different sources, it also allows planners to evaluate the effects of measures on many different aspects. Because response times are very short, the instrument can be used in interactive workshops with specialists and stakeholders. In this way, authorities can formulate effective noise abatement strategies in a

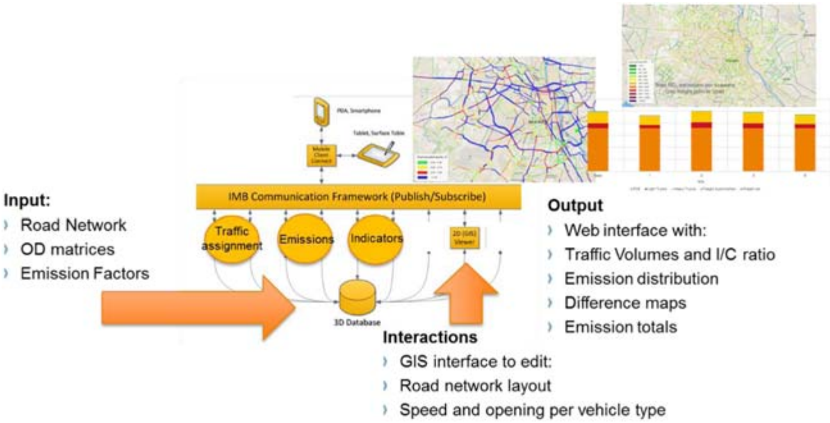


**FIGURE 10.12** Overview of the decision support system on the basis of Urban Strategy. *GIS*, Geographic information system; *OD*, origin–destination.

very short time span while involving the relevant parties. The starting point of Urban Strategy was to use existing state-of-the-art models that were already implemented. To be able to let different models cooperate, the following elements were developed: a uniform data model to create one shared data tore, a communication framework for communication between the models, and interfaces to view and manipulate the data.

Fig. 10.12 shows the overall setup of the decision support system (DSS) on the basis of Urban Strategy. On the basis of the input, namely, trip productions, attractions, mode wise OD matrices, socioeconomic and land use characteristics, zone and road network maps, fleet characteristics, emission factors etc., traffic assignments and emission calculations are performed by the DSS. Therefore changes in the road network can be assessed interactively.

### 4.6.2 Model parameters

To use Urban Strategy, a set of parameters is essentially required to calibrate the model, and these have to be created in compatible with the software. The brief description of these parameters has been given as below:

- *Coordinate system:* Universal Transverse Mercator system has been selected.
- *Road network:* links/roads (data on speed, capacity, length, etc.), nodes, and traffic zones have been created for the Delhi city (as shown in Figs. 10.5 and 10.6).
- *Buildings and basic coverage:* data imported from OpenStreetMaps (OSM)
- *Road traffic and OD matrices:* observed traffic data on different links and nodes, further the OD matrices developed in the trip distribution stage.

A volume averaging method has been used to assign the transportation demand (OD matrix) provided to the network. This means that the traffic is divided over several routes, depending on the available capacity and travel times on alternative routes. The assignment module allows multiple transportation modes to be assigned simultaneously. Therefore roads can be opened or closed for different types of vehicles. In the present study, Central Pollution Control Board, India (CPCB, 2000), emission factors for four types of freight vehicles and passenger cars in gram/kilometer for different age classes with deterioration factors have been used. On the basis of the age distribution, final emission factors were derived. Traffic assignment of the transportation demand yields traffic volumes on the road network (vehicles per 24 hours), and multiplication of emission factors leads to emission per vehicle type per meter link [g/(km 24 h)]. Summation over the vehicle types and links leads to the emission totals per 24 hours on the entire road network.

### *4.6.3 Visualization of traffic links, nodes, and traffic zone centroids*

Fig. 10.13 shows the screenshot from the two-dimensional module, which was analyzed in Urban Strategy based on the data discussed in previous sections. From the Fig. 10.13, it can be seen that nodes are denoted by red dots, and the centroids of traffic zones are denoted by blue dots. Urban Strategy is capable of showing all results in a three-dimensional (3D) interface. The 3D graphics can be built on the basis of a range of data types; however, the most basic 3D graphical representation can be built on the basis of building shapes and building heights. Building shapes have been imported from OSM, and in the absence of better data on building heights, all heights have been set to a default of 10 m.

## 4.7 Forecasting of freight trips from freight demand models

### *4.7.1 Freight trips*

The developed freight transport models are used to forecast the trips that are going to be generated in the City of Delhi. Of all the freight generation model variables, the population data over the years are available, and limited data for the other variables, namely, employment available for the year 2021, which is related to Census Update year in India. Using the growth factors for these variables, growth factors for other variables have been appropriately considered. From this exercise, the total trips productions and attractions for the year 2021 are estimated to be around 572,000, which increased with a growth rate of 4% per annum.

### *4.7.2 Traffic loads on the road network*

In 2002 and 2009, CSIR-CRRI has conducted a study to estimate traffic loads in terms of vehicle kilometers traveled (VKT) on the road network of Delhi and accordingly projected for the years 2010 and 2015 (CRRI, 2009). Using

**FIGURE 10.13** Screenshot from the two-dimensional module analyzed in Urban Strategy for New Delhi.

these data, the projections have been made from the growth factors for all the vehicle types. The estimated VKT for 2017 and forecasted VKT for the year 2021 are presented in Fig. 10.14. From Fig. 10.14, it can be observed that the estimated total traffic loads in terms of VKT are about 240 million and 300 million in 2017 and 2020, respectively. The VKT by freight vehicles is going to be about 10 million and 13 million in 2017 and 2020, respectively, which is having a share of about 4%. The growth of total VKT is increasing with 7% per annum growth, whereas freight vehicles growth is about 8% per annum.

## 5. Policy evaluations

### 5.1 Scenarios

To demonstrate the application of the developed freight demand model, the following policy scenarios have been defined, which have affect on emission loads from the traffic circulation:

#### *5.1.1 Scenario 1: Elimination of diesel goods vehicles older than 10 years*

Under this scenario, the removal of diesel vehicles older than 10 years from the vehicle fleet has been considered. The resultant vehicle fleet would reflect the current distribution of vehicles.

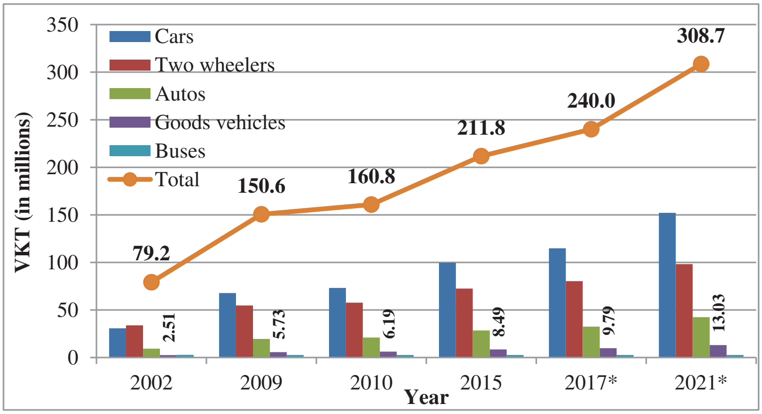


**FIGURE 10.14** Estimated vehicle kilometers traveled/day for different vehicle types for different years.
*Estimated in present study.

### 5.1.2 Scenario 2: Placement of a number of freight hubs in outer areas

Under this scenario, new logistics hubs at five locations are proposed, and all these locations lie outside of the city, which has 360 "internal" traffic zones, and correspond roughly to one of the eight "external" traffic zones. It was assumed that 20% of the external traffic originating from (i.e., entering the city through) the corresponding external traffic zone travels to the hub, and the freight continues on in light trucks (LTs) or GVs. The load from one HT corresponds to four GVs, or two light/medium trucks.

### 5.1.3 Scenario 3: Restriction of heavy trucks from entering a city center

In this, assessment of traffic impacts by restricting a certain area (central area) of Delhi for HTs has been carried out. All heavy traffic entering the cordon converted to LTs/vans, and all other heavy traffic diverted around the cordon.

### 5.1.4 Scenario 4: Elevated high-intensity corridor

A North–South high roadway capacity elevated road corridor without intersections connecting outer cordon location from one end of the city to other end, open for all modes has been considered.

### 5.1.5 Scenario 5: Fleet conversion to low-pollution vehicles

In this option, conversion of freight vehicles to electric transmission engine considered based on a future scenario where 100% of auto-rickshaws to electric, along with 17% of light, medium, and HTs. This would correspond to a large-scale conversion of auto-rickshaws, plus 4% per year converted to electric over a 4-year period. All other vehicle types and emissions stay the same (model uses 2017 emissions). Emissions of CO, NOx, benzene, and hydrocarbon assumed to be zero for electric vehicles, and PM10 remaining approximately the same as for the existing vehicle fleet.

#### *5.1.6 Scenario 6: Improved connectivity to rail hubs and airports*

This scenario has been conceptualized in the present study; however, there would be difficulty in predicting impacts on emissions without details on intended operations; therefore the evaluation has not been carried out in the present study, and this could be further analyzed in a future work.

### 5.2 Evaluation results

#### *5.2.1 Base scenario*

To evaluate the proposed policies, it is necessary to have base scenario where it shows existing conditions with no measures. Accordingly, the Urban Strategy has been applied with existing travel demand with no measures and estimated the evaluation parameters, which are given below:

- Traffic volumes (#/24 hours)
- Traffic volume/capacity (V/C)
- Emissions for each vehicle type, per substance (g/km)
- Emission totals per substance (g/km)

The web interface was built in Urban Strategy, and in this interface, spatial distributions can be viewed for the above evaluation parameters. The traffic V/C values and NOx emission loads for the base scenario are shown in Figs. 10.15 and 10.16, respectively. From Fig. 10.15, it can be seen that the links with a high probability of congestion (shown as blue-colored links) are very high in the total network of Delhi. From Fig. 10.16, it can also be seen that the links with a high probability of NOx loads (shown as red-colored links) are very high in the total network of Delhi.

#### *5.2.2 Policy scenarios*

As discussed above, the selected policy scenarios have been evaluated in Urban Strategy, and the spatial distributions of the evaluation parameters have been displayed using the developed interface. The summary of the results from the policy evaluation is given below:

- As expected, Scenario 1 (elimination of diesel freight vehicles older than 10 years) reduces the emissions of all substances in the entire city. Here,

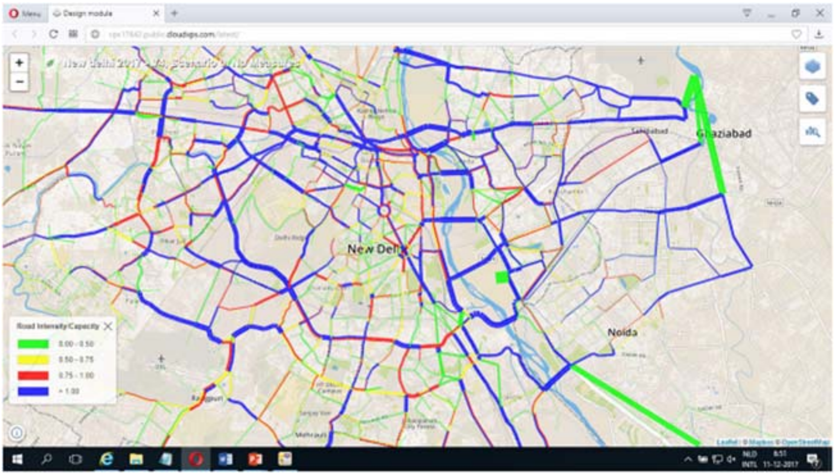


**FIGURE 10.15** Result of traffic flows in relation to capacity in base scenario.

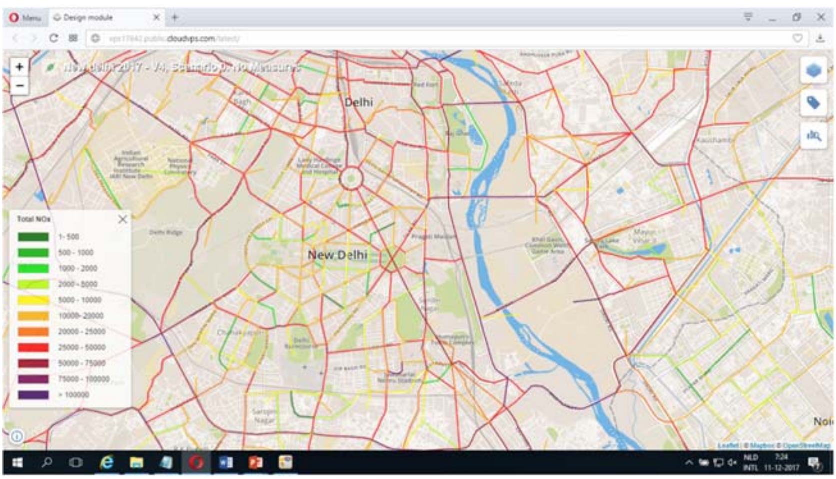


**FIGURE 10.16** Spatial distribution of NOx emissions due to road traffic in the base scenario.

NOx stays below the acceptable levels in the city. The other scenarios show different spatial patterns of NOx reduction.

- The Scenario 2 (placement of a number of freight hubs in outer areas) shows a slight overall increase because the same freight is carried in smaller vehicles, and the emissions will be redistributed. Fig. 10.17 shows the spatial distribution of NOx emission change due to Scenario 2.
- The Scenario 3 (restriction of HTs from entering a city center) shows only slight overall decrease partially because truck routes are diverted

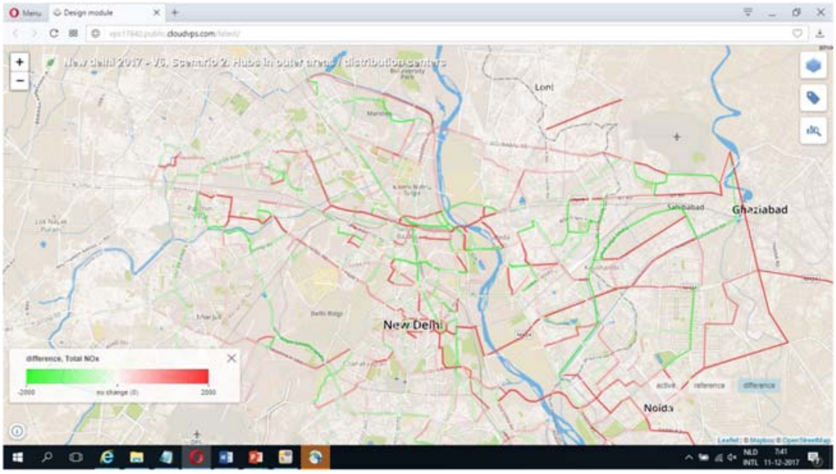


**FIGURE 10.17** Spatial distribution of change in NOx emission due to Scenario 2.

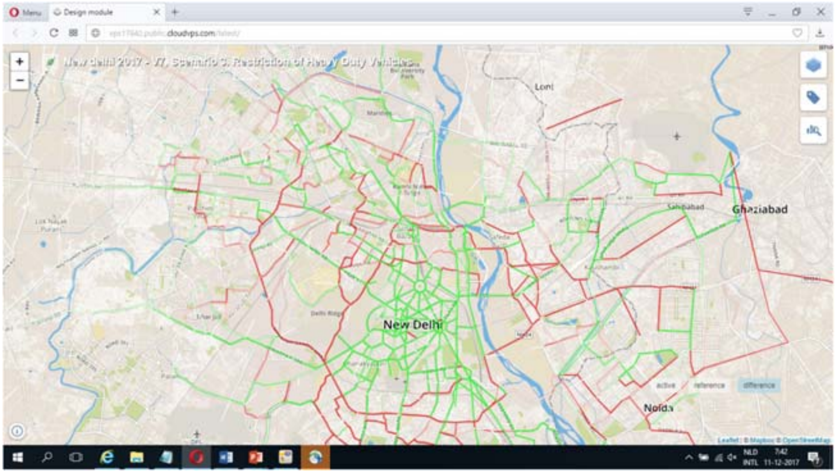


**FIGURE 10.18** Spatial distribution of change in NOx emission due to Scenario 3.

around the city, and emissions will be redistributed. Fig. 10.18 shows the spatial distribution of NOx emission change due to the Scenario 3.

- Under the Scenario 4 (elevated high-intensity corridor), the traffic will be routed more efficiently, there is a slight decrease in emissions. Fig. 10.19 shows the spatial distribution of NOx emission change due to this scenario.
- The Scenario 5 (fleet conversion to low-pollution vehicles) also shows the reduction of the spatial distribution of NOx emission due to fleet

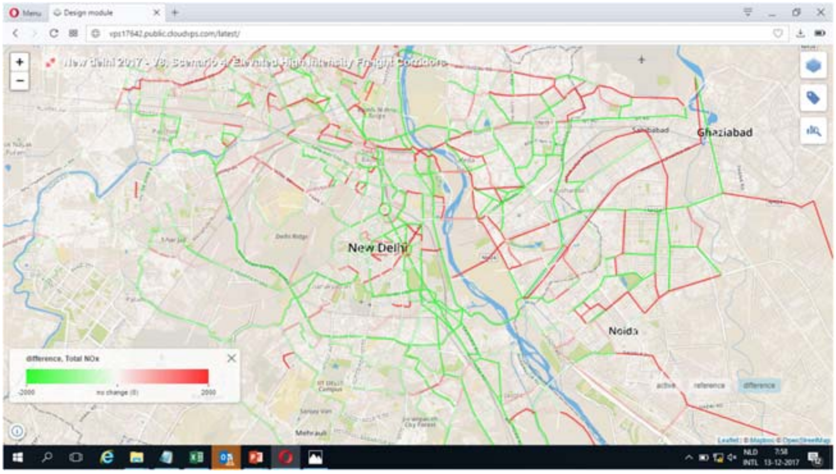


**FIGURE 10.19** Spatial distribution of change in NOx emission due to Scenario 4.

conversion. This scenario will have an overall positive effect on air pollution reduction, similar to Scenario 1.

## 5.3 Emission totals

The emissions calculated per road segment per substance per vehicle type have been summarized in the form of indicators of emission totals. Fig. 10.20 shows the breakdown of the emission totals for different road transport vehicle types in Delhi for different substances for base scenario. From Fig. 10.20, it can be seen that Passenger Car Equivalents account for most of the road traffic emissions for all substances. This is because of the fact that the traffic volume of passenger transport is much larger than the other categories. The result also shows that HTs do contribute substantially to the NOx emissions, followed by the LT as shown in Fig. 10.20. Fig. 10.21 shows the comparison of emission totals for road transport in Delhi for different scenarios. Because the contribution of freight transport is limited, the effect of different scenarios can be seen more clearly when only looking at the freight emission totals as shown in Fig. 10.22.

From Fig. 10.22, it can be seen that the removal of diesel vehicles older than 10 years, Scenario 1, shows 4%–11% decrease in total CO, NOx, and PM10 emissions and negligible difference in benzene or hydrocarbon levels. The freight hubs (Scenario 2) and heavy vehicle restrictions (Scenario 3) may lead to increased overall emissions if there is no change to the emissions profile for the vehicles that replace them. Introduction of a high-capacity corridor (Scenario 4) will lead to a slight decrease in emissions. Introduction of electric freight vehicles (Scenario 5) shows promising results

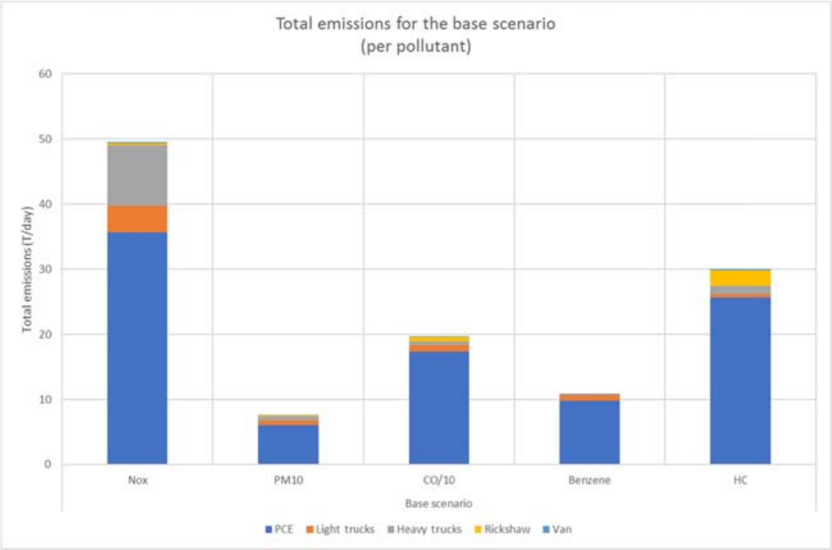


**FIGURE 10.20** Breakdown of emission totals for road transport vehicle types in Delhi for different substances.

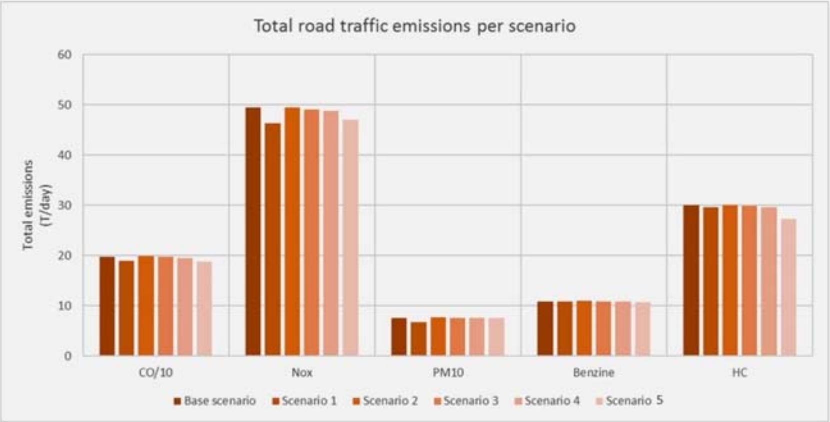


**FIGURE 10.21** Comparison of emission totals for road transport in Delhi for different scenarios.

for reduction in emissions, dependent on the penetration rate achieved. The estimated traffic loads and emission loads from vehicular traffic from Urban Strategy System based on developed freight demand model in the present study would enable the policy makers and authorities in taking decisions to improve overall air quality in the city of Delhi.

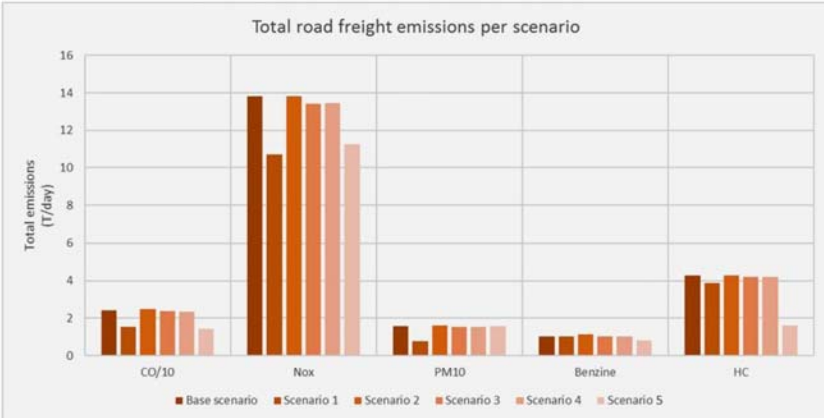


**FIGURE 10.22** Comparison of emission totals for road freight transport in Delhi for different scenarios.

## 6. Concluding remarks

Understanding and forecasting freight movements are critical to plan for future transportation in terms of capacity augmentation, operation, preservation, safety and security, energy, and economy investment needs. Many demand forecasting models and data sources are more appropriate for passenger transportation than for freight transportation. Hence, creating better data and models is highly needed to enable planners to better predict freight movement and design better informed policies. In view of this, the present study has been conceptualized to study on urban logistics and the city of New Delhi, that is, the National Capital Territory of Delhi, India, has been selected as a study area. By conducting field surveys, metrics of city logistics, development of traditional four-stage freight travel demand model, and evaluation of relevant transport policies have been carried out. The summary is given below:

- Based on the results of estimated traffic loads and emission loads from vehicular traffic, it can be said that the contribution of passenger vehicle movements to road transportation emissions is dominant in comparison to road freight movements.
- The developed urban freight traffic model in Urban Strategy in the present study is feasible for Delhi and able to evaluate the effect of different freight-related policy scenarios.
- Removal of diesel vehicles older than 10 years shows 4%–11% decrease in total COx, NOx, and PM10 emissions and negligible difference in benzene or hydrocarbon levels caused by freight traffic.
- Freight hubs and heavy vehicle restrictions may lead to increased overall emissions if there is no change to the emissions profile for the vehicles

that replace them. The hubs will only be effective if they are combined with measures to lower fleet emissions, such as the use of electric vehicles.

- Introduction of electric freight vehicles shows promising results for reduction in emissions, dependent on the penetration rate achieved.
- The impact of measures only targeting freight movements will be limited because of its relatively small contribution to air pollution. Therefore it would be valuable to apply this system on the integrated challenge of the city of Delhi with regard to air pollution and traffic noise. More in general, balancing between urban planning, mobility planning, and environmental planning to accommodate (economic) growth and improve the quality of life of its citizens.
- The Urban Strategy system based on developed freight demand model in the present study would be helpful in evaluating appropriate transport policies and also enable the policy makers and authorities in taking decisions to improve overall air quality in the city of Delhi.

The findings of this study provide insight into the effects of measures on the traffic flows and related emissions. These insights can be developed further in future study on this topic by:

- Refinement of the link capacity and speed profiles through the actual measurements to improve the output in terms of congestion prediction.
- Refinement of emission factors based on speed and congestion factors to avoid underestimations of emissions and more realistic estimation of the impact of scenarios.
- Concentration and exposure calculations can be added to provide a different comparison of scenarios because shifting emissions out of densely populated will affect health without affecting emission totals.
- Adding noise emissions and exposure as parameters in output will provide a more integrated view on the situation and the impact of scenarios.

## Acknowledgments

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Chapter 11

# Predicting container terminal daily workload: a Middle East port case study

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## Highlights

- Lack of information on truck arrivals for import container pick-ups in port container terminals.
- Application of data retrieved from **t**erminal **o**perators **s**ystems.
- Re-specification of time-of-day models applied in passenger transport.

## 1. Introduction

Competition among container ports continues to increase as terminals strive to win a leading place in the international market. To achieve that, terminal operators make efforts to attract more carriers. They automate handling equipment, provide new services, speed up the old ones, and reduce costs by using efficiently the available equipment and personnel. In addition, the difficulties inherent in managing port operations because of the uncertainty of demand and the complexity of planning processes necessitates the application of advanced tools that support every stage of planner's decision-making process.

The current wave of big data and digitalization creates new opportunities for container terminal planning and management. Business analytics using terminal operational data provides insights to operators and assist them to reduce uncertainties and understand the causes of inefficiencies,

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disruptions, and anomalies in inter- and intra-organization operations. However, the information on the schedules of both seaside and inland container transport remains unreliable. Supply chain visibility is important to enable tracking the position and who is handling the container at any time.

Trucks remain the predominant transportation mode for executing import container pickups, and terminal operators can benefit from an estimation of the time that a container is to be picked up. Road carrier companies target in performing their operations with minimum time and cost. On the other hand, terminal operators make an effort to develop efficient schedules and rules to ensure that the terminal performance indicators such as truck turnaround time, short queue lengths and gate waiting time remain minimal (Azad et al., 2017). To efficiently plan everyday operations and equipment and human resource allocation container terminals have tried to implement truck appointment system (TAS) to manage external truck arrival traffic (Zehendner and Feillet, 2014). Workload forecasting of import container pickups is of essential importance for the optimal allocation of equipment and personnel. This information can also assist at encountering delays and bottlenecks in the landside operations. Some ports have tried to implement TAS, but, in general, information on the pickup patterns of import containers remain scarce (Kourounioti and Polydoropoulou, 2018). Finally, because of the lack of accurate information, yard planners make stacking decisions mostly based on their experience. Thus, if the time that an import container would be picked up was known in advance, operators would be able to organize the yard appropriately so as to be able to retrieve easily containers with higher pickup probabilities. In addition, from the landside, the receivers of goods still rely on carriers to provide with accurate information on when containers will be delivered.

Literature review revealed limited application of behavioral models predicting time-of-day (TOD) decisions related to freight transportation and especially to container terminal operations. This chapter applies TOD methodologies to predict daily import pickup container patterns in a middle eastern port container terminal. Aggregated data directly available from the terminal operation system (TOS) of the terminal can be apply to develop models that calculate the probability of an import container to be picked up by a truck.

This chapter is structured as follows. In the next section, we give a brief overview of the applications of TOD models in freight transport. Section 11.3 describes the methodology and the data collected for model development. Model estimation results are presented in Section 11.5, whereas Section 11.6 concludes the chapter.

## 2. Literature review

An extensive literature on TOD models addressing passenger's time choices (Hess et al., 2007; Lemp et al., 2010; Holyoak, 2007; Kristoffersson and Engelson, 2008), whereas the application of scheduling models in freight transport literature remains scarce. Time choice has already been included in national model such as in Norway and in the Netherlands (Halse et al., 2010; Significance, 2010), but these studies mostly focus on reliability, but they do not include freight transport forecasting models.

Applications of scheduling models have been applied in New York City to test how to shift urban deliveries to off-peak night hours (Holguín-Veras et al., 2012; J et al., 2006). Arrival times of drayage containers in port container terminals have been mostly addressed using simulation models. Such studies were developed to check the effectiveness of policies trying to address the phenomenon of service peaks in the gates of terminals and to decrease the emissions caused by high way times. The introduction of PierPASS in the Californian ports of Los Angeles and Long Beach that imposes high fees to shippers when they pick up or deliver containers during the morning times have been studies researched in the studies by (Holguín-Veras et al., 2008; Giuliano and O'Brien, 2007).

The choice of tour period and the choice of tour start time in the port of Calgary in Canada were modeled using a combination of Monte Carlo simulation and choice models using revealed preference data (Hunt and Stefan, 2007). De Jong et al. (2016) developed a choice model for the period for road freight transport. The model was based on a stated preference (SP) survey among the shippers in Flanders and investigated the period sensitivity of road freight transport to changes in travel time and cost (De Jong et al., 2016).

Ellison et al. (2015) conducted SP experiments to Australian shippers to estimate latent class models to identify their choice to use toll roads, the number of trips inside a tour, the type of truck, and the departure time (Ellison et al., 2015). Finally, Kourounioti and Polydoropoulou (2018) develop TOD models for import containers using data retrieved from TOS. Model results indicated that the receiver of goods and container characteristics were among the main factors affecting pick up TOD. The developed TOD models can be used to calculate the probability of drayage truck arrival times.

## 3. Methodological framework

### 3.1 Data

The methodology is tested with aggregate data collected from a container terminal in the Middle East during 2013.

**Container characteristics:**

1. International Organization for Standardization (ISO) code (if it was a 20’ft or a 40’ft container)
2. Reefer (if it was a refrigerated container or not)
3. Shipping line of the container
4. Port of origin
5. Weight
6. Date and time the container was unloaded in the terminal
7. Date and time the container was picked up by a truck

The database contained 318,794 observations and was cleaned from missing and bad quality data (e.g., negative times). Corrections were made to dates and pieces of information that were not entered in an appropriate format. The new clean database consisted of 202,307 observations. Dummy variables were created to indicate the pick up day and month, the container ISO, and reefer containers.

For every container information on size, cargo type, exact date, and time of pick up was extracted from the TOS. The container terminal operates 12 hours (6:00 a.m. to 6:00 p.m.) per day all the week apart from Sunday. Data analysis (Fig. 11.1) showed that container pickups reach a peak at noon (12:00 p.m.). In addition, 62.14% of containers were 20’ft, and 4.72% were reefer containers. The majority of containers were picked up on Monday. The port is located in a Muslim country; thus on Friday, a prayer day for the local population, fewer pickups are conducted.

## 4. Model specification

This research considers import containers and makes the assumption that pickups are not linked with an export dropoff. Before model development,

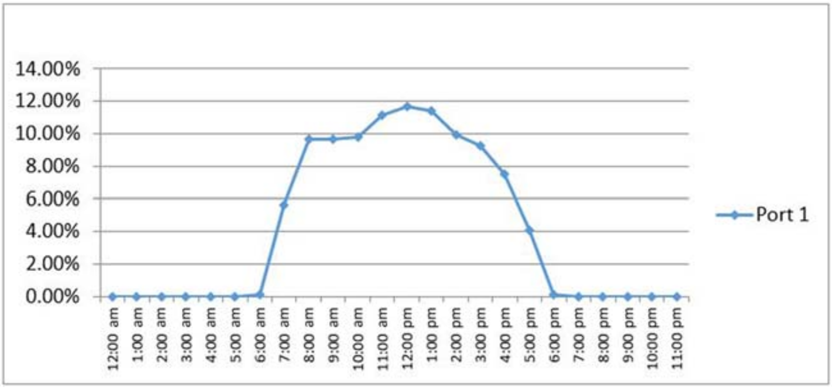


**FIGURE 11.1** Pick up time-of-day distribution.

we interviewed professionals in the port who provided insights on the parameters that usually influence pick up time. For this research, we asked the terminal operator to retrieve data from the terminal TOS. One of the main problems of this research was to develop trust with the terminal operator in order for him to provide us with the data. In addition, the data we inserted in the model were not easy to retrieve because the TOS was not designed in a way that permits data collection. Based on our a priori expectations on alternative factors affecting TOD, several models were estimated. Other factors included in the modeling effort are port of origin, shipping line, and weight, which were found statistically insignificant and were not included in the final model. The following parameters were found statistically significant, and we expect that they would influence TOD as explained below:

1. Container characteristics such as dimension, if it is a reefer or not. Especially, reefer containers that are subject to time restrictions are expected to present different pickup TOD patterns.
2. Day of the week in which the pickup was realized. Road conditions such as congestions are also represented by this variable and are expected to influence TOD utilities.

Based on these assumptions, we insert the abovementioned variables in the choice models to validate and quantify their impact on the pickup TOD.

To define the probability of truck arriving to pick up a container on a specific time slot, a multinomial logit model is developed, with $i$ denoting a time slot and $n$ representing a container. The objective is to model the percentage of containers being picked up on time slot $i$. We define $X_n$ as the matrix with as many rows as there are time slots, where $X_{in}$ corresponds to the $i$th row of $X_n$. $X_{in}$ is a row vector that contains the restrictions of time slot $i$ and the characteristics of the container $n$. We define $F(i|X_n;\beta)$ as a function that predicts the probability that a container n is being picked up in time slot $i$ where $\beta$ is a vector of unknown parameters. The number of alternative time slots is denoted as $J$. We assume that a container is being picked up on the time slot with the highest utility. The utility of time slot $i$ for container $n$ is as follows:

$$U_{in} = X_{in} \cdot \varepsilon_{in} \tag{11.1}$$

where $\varepsilon_{in}$ is an error term that accounts for measurement errors. The explanatory variables are inserted in the model through a linear relationship $X_{in\beta}$. The error terms, $\varepsilon_{in}$, $i = 1, \ldots, J$, were assumed to be independently and identically distributed standard random variables (Ben-Akiva and Abou Zheid, 2013). Hence, the probability for a container $n$ to be picked up at a time slot $i$ was given by the following equations (Ben-Akiva and Lerman, 1985).

$$P_n(i) = \frac{e^{V_{in}}}{\sum} j \in C_n e^{V_{jn}} \tag{11.2}$$

where $C_n$ is the feasible choice set given in each individual; and

$$U_{in} = V_{in} + \varepsilon_{in} \tag{11.3}$$

where $V_{in} = X_{in}\,\beta$ is the systematic utility.

The TOD models are developed to check the assumption that the pickup TOD is affected by container characteristics such as container size (20'ft or 40'ft), cargo type (standard, refrigerated, or hazardous cardo), days of the week, and seasonality. Fig. 11.2 presents the methodological framework.

In an effort to smooth the discontinuity of the utility function and to reduce the number of unknown parameters (Ben-Akiva and Abou-Zheid, 2013), alternative specific constants were specified as continuous functions of time. To discretize the continuous time, we incorporate trigonometrical equations in the utility functions. The utility functions are presented below:

$$U_i(t) = \sum_{\nu}^{j} v_j(t_h)^* x_j + \varepsilon_i \tag{11.4}$$

where $v(t_h)$ is the trigonometrical equation and $t_h$ is the middle of the choice interval (Jong et al., 2003; Börjesson, 2008; Koster, 2012; De Jong et al., 2014).

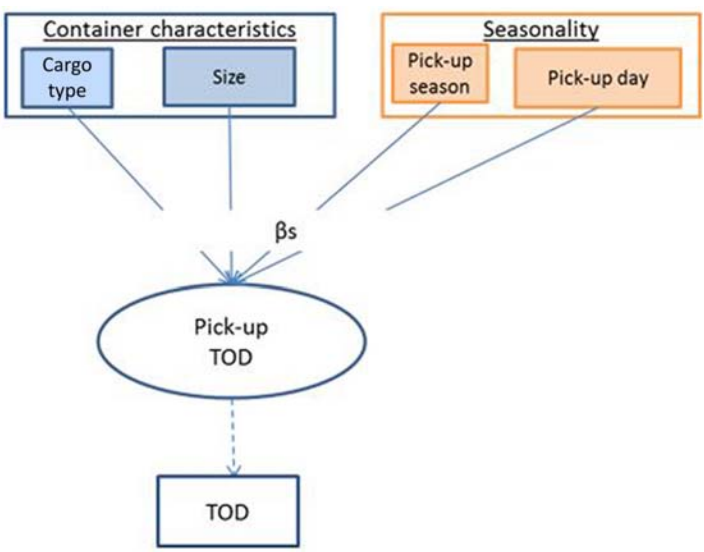


**FIGURE 11.2** Methodological framework.

**TABLE 11.1** Choice intervals.

| Nr | Interval | Duration | Middle | Number of pickups |
|---|---|---|---|---|
| 1 | 6:00 a.m.–9:00 a.m. | 3 h | 7:30 a.m. | 44,671 (22.08%) |
| 2 | 9:01 a.m.–12:00 p.m. | 3 h | 10:30 p.m. | 66,511 (32.88%) |
| 3 | 12:01 p.m.–3:00 p.m. | 3 h | 1:30 p.m. | 66,122 (32.68%) |
| 4 | 3:01 p.m.–6:00 p.m. | 3 h | 4:30 p.m. | 25,003(12.36%) |
| Total | | 12 h | | 202,307 |

$$v_j(t_h) = a_{1i}\sin^2\left(\frac{2K\pi t_h}{24}\right) + \ldots\ldots\ldots + a_{\nu i}\sin^2\left(\frac{2K\pi t_h}{24}\right) \tag{11.5}$$

where $U_i$ is the utility equation of the interval $I$[1], $v_i(t_h)$ is the smoothing equation of discrete variables to continuous, $t_h$ is the middle of the choice interval, $x_j$ is the explanatory variables (dummy variables), and $\varepsilon_i$ are error terms.

The sin trigonometrical equation was chosen because its shape corresponds to the distribution of pickups in the terminals.

## 5. Model estimation results

This section presents the model results for calculating the probability of a container to be picked up in a specific time slot. The examined terminal operates 12 hours, 7 days per week. For the model development, we divided the day into four 3-hour intervals, as it shown in Table 11.1.

During the second and the third intervals, almost the same number of pickups was realized. In the first interval, 22% of containers was picked up, and in the fourth, 2.36% of containers was picked up.

Model estimations were conducted using Python Biogeme 2.4 (Bierlaire, 2015). The results of the model are presented in Table 11.2. The available data were inserted in the model. Expected results included that the pickup profiles of 20'ft and reefers containers would be different compared with 40'ft and nonreefer containers. Finally, it was expected that the particular days would have an influence on the pickups. In this study, the introduction of the days of the week is very important because they reflect the road restrictions imposed by the terminal operators.

For model simplification, a dummy variable was created for the pickups made from Monday to Thursday because during these days, the same

[1]We tested additional functions such as the combination of sin and cos, but ultimately the best results were obtained by applying the square sin function.

restrictions are imposed. The following explanatory variables were inserted in the models: x1 = dummy variable for 20'ft, x2 = dummy variable for reefers, x3 = dummy variable for pick ups made on Mondays, x4 = dummy variable for pick ups made on Tuesdays, and x5 = dummy variable for pick up made on Saturdays. The exact value of K is calculated via a trial and error procedure of estimating models with various K and comparing their log likelihoods. It should be noted that K = 1 represents 24 hours. Because the pickups were conducted only 12 hours per day, we used only K = 1/2 and K = 3/2.

**TABLE 11.2** Model results.

| Variables | Parameters | Values | $t_{stat}$ |
|---|---|---|---|
| ***Sin*² time equation of the constant** | | | |
| $Sin^2(\pi * t_h/24)$ | $a_1$ | −0.893 | −36.60 |
| $Sin^2(3\pi * t_h/24)$ | $a_2$ | 6.15 | 72.51 |
| **20'ft * *Sin*² time equation** | | | |
| 20'ft * $Sin^2(\pi * t_h/24)$ | $a_{11}$ | −0.306 | −11.15 |
| 20'ft * $Sin^2(3\pi * t_h/24)$ | $a_{21}$ | 0.111 | 2.07 |
| **Reefer * *Sin*² time equation** | | | |
| Reefer * $Sin^2(\pi * t_h/24)$ | $a_{12}$ | 0.842 | 12.09 |
| Reefer * $Sin^2(3\pi * t_h/24)$ | $a_{22}$ | −0.101 | 1.98 |
| **Monday * *Sin*² time equation** | | | |
| Monday * $Sin^2(\pi * t_h/24)$ | $a_{13}$ | −3.94 | −3.94 |
| Monday * $Sin^2(3\pi * t_h/24)$ | $a_{23}$ | 0.144 | 0.83 |
| **Tuesday * *Sin*² time equation** | | | |
| Tuesday * $Sin^2(\pi * t_h/24)$ | $a_{14}$ | −0.218 | −6.04 |
| Tuesday * $Sin^2(3\pi * /24)$ | $a_{24}$ | 0.182 | 1.50 |
| **Saturday * *Sin*² time equation** | | | |
| Saturday * $Sin^2(\pi * t_h/24)$ | $a_{15}$ | −0.237 | −4.53 |
| Saturday * $Sin^2(3\pi * t_h/24)$ | $a_{25}$ | 0.128 | 0.73 |
| Number of observations | 202,307 | | |
| Finallog (L) | −242,536.871 | | |
| Initiallog (L) | −276,675.242 | | |
| Adjusted Rho Square | 0.183 | | |

To better interpret the model results, Fig. 11.3 presents and compares the normalized profiles of every parameter (Ben-Akiva and Abou-Zheid, 2013). To interpret the parameters of each pick up time slot, the function values were calculated for variable. Then the utility equation of each variable is divided by the utility calculated at the base time 10:30 a.m. (interval 2). For example, the line "twenties" represents the sun $a_{11}\sin^2\left(\frac{\pi t_h}{24}\right) + a_{21}\sin^2\left(\frac{3\pi t_h}{24}\right)$ divided by the utility at the time 10:30 a.m. (interval 2). Fig. 11.3 shows the normalized pick up time profiles for each of the container characteristics.

Twenties presented a higher value in the second time interval and lower in the last interval. The same applies to reefer containers, as the recipients want to pick them up as fast as possible because of the sensitive products they carry. On Mondays and Saturdays, the highest utility is presented in the first interval, whereas on Tuesday, it is more likely to import pickup containers in the third interval.

## 6. Conclusions

This chapter tries to develop a methodology that addresses the problem of increased waiting times in the container terminals by predicting the arrival times of trucks to pick up containers. This information will help operators optimize the daily planning of personnel and equipment, decrease waiting times at the gates, and decrease environmental pollution. In emerging countries where low labor costs make automation less cost-efficient and truckers and terminals oppose the application of TAS, such predictive models can become beneficial. In addition, the application of behavioral models in freight permits to capture the factors that influence freight-related choices and enable researchers to depict the complex interactions created between the stakeholders that drive freight demand (Ben-Akiva and Abou Zheid, 2013).

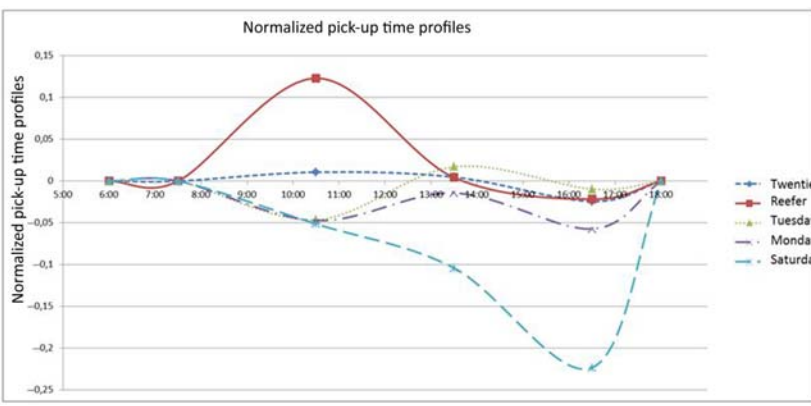


**FIGURE 11.3** Comparison of relative utilities.

One of the most important contributions of the research is the application of data available directly from terminals' TOS to develop models that explicitly capture the influence of container characteristics and day of the week at the distribution of drayage truck arrivals for import container pickups. During model specification, we consulted with the professionals in the port who provided insights on the parameters that usually influence pickup time. The results of the research prove that applying data already available in port container terminals, it is possible to develop predictive models that can be used as tools for efficient daily planning.

Additional information such the commodity and the receiver of the goods is expected to increase the predictability of the models. Specifically, more information on the characteristics of the recipients of goods can provide interesting insights regarding behavioral issues; for example, it can quantify how specific characteristics such as company type, size, or distance from the terminal can affect TOD related decisions.

TOD models can be used alongside with TAS to compensate for the unknown pickup times of the containers without appointments. Regarding future research, additional historical data can be acquired. It is believed that with a larger dataset, some of the variables that were found insignificant might become significant. Furthermore, similar models can be developed with data from other container terminals and compare the results. Finally, the collection of innovative SP data, and their combination with the data is expected to increase the predictability of the TOD models.

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Chapter 12

# Synthesis

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## 1. Introduction

This book provides a collection of chapters aiming to help decision-makers in developing and emerging countries to deal with the manifold problems of national-level, descriptive, and predictive freight transport modeling. Emerging countries are characterized by rapidly growing economies and fast urbanization, combined with a significant transport network capacity backlog because of lacking or aged infrastructure. Freight networks have to accommodate strong fluctuations in consumption patterns because of an increase in the population and welfare in general, as well as newly emerging industries that develop new activities. Hence, decision-makers are in urgent need of transportation system models that help them to explore future development scenarios and provide them with information to plan infrastructure investments effectively. The limited budget and the urgency to find fast solutions to the growing problems lead policy makers and transport planners to consider the use of either very simplified transport models or state-of-the-art models from developed countries. These latter models such as the Dutch, Swedish, and Norwegian national freight models were built to represent different national transport needs, development rates, and economy structures and usually do not reflect sufficiently the needs of emerging countries. In addition, they often place stricter demands on data availability and quality than developing or emerging countries can fulfill. In short, emerging and developing countries face different issues in freight transport modeling than developed countries. This book discusses the general challenge and develops cases for different countries, around a framework of issues in national freight modeling, as proposed earlier by de Jong, et al[1]. The framework is built on

[1] de Jong G., Tavasszy L., Bates J., Grønland S.E., Huber S., Kleven O., et al. The issues in modelling freight transport at the national level. *Case Studies on Transport Policy*, **4** (1), 2016, 13−21. https://doi.org/10.1016/j.cstp.2015.08.002

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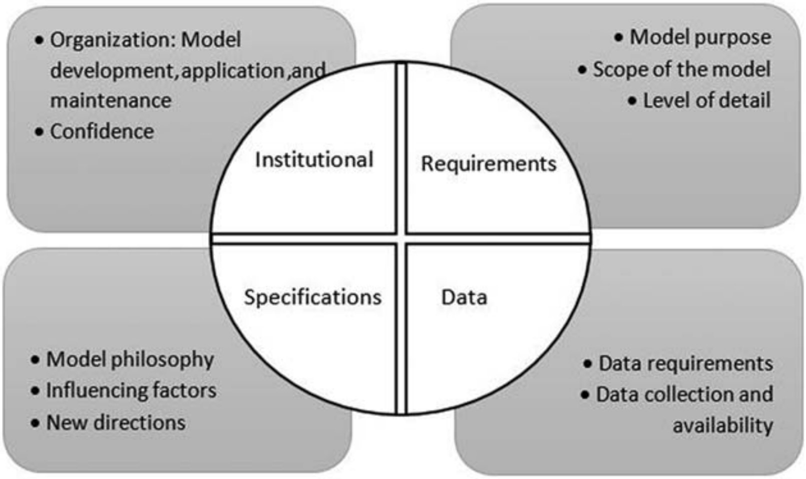


**FIGURE 12.1** Issues in modeling freight transport at the national level. *Source: Adapted from de Jong et al., (2016)*[1] *and taken from Chapter 2.*

four types of issues: (1) institutional issues, (2) requirements from policy makers, (3) choice of model specifications for specific purposes, and (3) data needs and availability. The framework is shown in Fig. 12.1 below.

Institutional issues deal with administrative challenges related to the development, application, and maintenance of the models and the level of confidence that policy makers can have on model results. The scoping of the model, the purpose behind model development, and the level of detail required by the model fall into the requirements category. Possible specification issues deal with the choice of the factors to include in the model, the model philosophy, and the inclusion of advanced modeling techniques and considerations. Finally, one of the most challenging issues for freight transport modelers is the lack of good quality data and the limited resources assigned for data collection activities.

The 11 chapters presented in this book belong to two categories: (1) those describing approaches to successfully address related to model development and (2) those demonstrating successful applications of models already specified for developed countries. Together, they cover the whole spectrum of issues painted earlier. Table 12.1 shows the focus areas of the chapters of this volume.

The aim of this chapter is to synthesize the approaches and the solutions presented in the book. The chapters are categorized based on the types of issues they have to deal with in a more concentrated way and aims to help the readers develop an overview of solutions that have been applied

**TABLE 12.1** Coverage of topics across chapters.

| | Approach | | | | Applications | | | |
|---|---|---|---|---|---|---|---|---|
| Chapter | Inst | Req | Specs | Data | Inst | Req | Specs | Data |
| 1 | • | • | • | • | | | | |
| 2 | • | | | | • | | | |
| 3 | • | • | • | | | | | |
| 4 | | | • | • | | | | |
| 5 | | | | • | | | | • |
| 6 | | | | | | • | | |
| 7 | | | | | | • | • | |
| 8 | | | | | | | • | • |
| 9 | | | | | | | • | |
| 10 | | | | | | | • | |
| 11 | | | | | | | • | • |

*Inst, Institutional; Req*, requirements; *Specs*, specifications.

successfully. The remainder of the chapter is structured as follows: Section 12.2 presents the institutional aspect, Section 12.3 presents the requirements, Section 12.4 presents the specification aspects, and Section 12.5 focuses on data issues. Section 12.5 summarizes the main conclusions.

## 2. Institutional issues

Institutional challenges are developed around two pillars. The first challenge deals with organizational perspective by ensuring that all stakeholder groups are being involved and their needs and requirements are being represented during model development. The engagement of all responsible authorities establishes the efficient and effective allocation of tasks and responsibilities and ensures not only the development of the model but also its maintenance. The second pillar deals with the level of confidence that transport planners can have to model outputs and results. In Chapter 1, Celebi reflects on the institutional issues of emerging countries and gives some approaches applied in Turkey to solve these issues.

The development of freight models in emerging countries usually involves a large number of agencies and authorities on national, regional, and local levels with complexities in communication and cooperation and difficulties in the alignment of responsibilities, needs, and goals. This environment leads to the development of a very diverse set of models that deal with different aspects, use different methods, provide different results, and have difficulty communicating with each other. Cooperation between the responsible agencies is essential to avoid difficulties in setting objectives and identifying a common plan. Therefore, model improvement requires cross-jurisdictional coordination. For example, at the time of writing, three different freight plans exist in Turkey, issued and controlled by different directorates, with each plan proposing different policies. This makes it difficult to reach a consensus and develop a common freight transport policy. To cope with these issues, the Turkish Ministry of Transport issued a directorate that makes it obligatory for all future transport modeling efforts and all regional and local plans to follow the guidelines set in the national transport masterplan.

To better deal with institutional complexities that surround the application of transport models, Anagnostopoulou et al. in Chapter 2 address the representation of actors, including their needs and goals, in transport model design and application. Building on a case for the port city of Thessaloniki, Greece, the authors propose a stakeholder consultation framework that focuses on setting objectives and on agreeing on common priorities. The representation of all stakeholders is crucial for the identification of possible conflicts and for ensuring the identification of mitigation actions. The framework supports the development of a common vision that can be translated into strategies and goals for the future development of transport infrastructure. In addition, it supports consensus on the criteria and performance indicators to assess the effectiveness of proposed policies, as well as on the acceptance of model outputs. Finally, the framework supports the continuous engagement of stakeholders, even after modeling consultations, to ensure that they give feedback and that policies are continuously improved.

The implementation of the framework in the port city of Thessaloniki proves that its transferability is possible for two reasons: (1) Thessaloniki is a city, which is now emerging from a financial crisis and faces a very fast economic development, as the privatization of the port of Thessaloniki is expected to lead to an increase in the port traffic; (2) it sets a good example for the interaction of the transport network with freight facilities because emerging economies. Because of low labor costs, high proximity to large markets, and land availability, these constitute a preferred location for the development of freight facilities. The implementation of the framework established a strong collaboration between public and private stakeholders, resulting in gradually improved and more accurate traffic models and the provision of more accurate information to the industry. In addition, model results inform decision-making about the development of the road network connecting the port to the main road arteries to the Balkans and the South of Greece via the city of Thessaloniki.

The active engagement of the private sector is also related to an institutional issue described by Celebi in Chapter 1. Companies operating in emerging countries usually face an unstable environment because of frequently changing regulations such as direct price controls by government, regulation of international trade and finance systems, and, overall, very high levels of uncertainty. Preferably, models and their applications should allow policy makers to take these complexities into account. Often these concerns are signaled earlier by industry than by government. The active participation of companies in the setting of requirements for model development ensures the representation of their needs and priorities.

One additional example of poor coordination between authorities of different countries with conflicting interests and different enforcement capabilities is the one of Chile and Argentina, discussed in Chapter 3. These countries require bilateral agreement to allow for the construction of a connecting tunnel. The necessary long-term commitments cannot be guaranteed because of continuous changes in government at various levels. A common initiative for all Latin American countries, coordinating actions and ensuring participation of all members, could deepen and enrich the process of sustainable planning by the integration of infrastructure. This would also imply a supporting modeling framework that is able to predict tans-national effects of freight network measures, along with the distribution of benefits. In this case, the impacts of freight transport modeling could clearly transcend national boundaries.

## 3. Model requirements

Setting the model requirements is an important issue faced during model development. It is not always clear what is expected from models, in terms of scope and detail of model outputs. Often decision-making processes pose a very specific context for models, such as in cost–benefit analysis. In other cases, the context is eclectic in nature, with models having to satisfy needs that differ situationally. The inputs, or the policy measures that the model is required to assess, will also influence the model requirements. Emerging countries witness great levels of uncertainty because of their volatile economies. These countries are characterized by high urbanization levels, rapid gross domestic product (GDP) growth, changing consumption patterns, and fast-evolving spatial distribution of economic activities. Models are asked, therefore, to capture the interactions between the economy and the transport system and understand the evolution of the macroeconomic parameters. Finally, policy measures are not always defined in terms of the functional performance of freight systems (e.g., times and costs) or are positioned at a different level of detail than the classical models will allow (e.g., freight operations as opposed to strategic investments). The relevant chapters present different salient points typical for emerging economies.

One of the greatest challenges faced by emerging countries is the strongly unbalanced economic development between the various regions of the country. To account for these discrepancies, models are required to take into consideration geographic, social, and economic parameters and the future economic development capabilities of each region. Lack of national statistics that could help understand and predict economic development trends and their effects on the transport network constitutes a frequent problem in emerging economies. To cope with this issue, Turkish modelers, as Celebi presents in Chapter 1, predict the economic development of certain regions based on their proximity to centers of economic development. In addition, as Turkish Railways are going through a phase of liberalization, changes in the use of the freight transport network are expected. This comes with new requirements for freight models on rail transport and its relation to regulatory policy.

In Chapter 3, Tapia and Sicra discuss the example of the counties of South America, which are made of regions with enormous economic and social disparities. Owing to their colonial tradition, these counties are mostly exporters of raw materials and importers of manufactured goods, whereas their networks are structured in a way that facilitates export flows to the ports and does not contribute to the development and connection of their local and regional economies. Hence, transport models are required to take into account these disparities and ensure regional integration not only at the national level but also at the global level. When asked to make decisions to improve the economic development of their regions, Latin American policy makers aim to integrate regional supply chains (RSCs) in global supply chains (GSCs). Hence, they need to be assisted by models required to understand the dynamics of RSC and to integrate them into the GSC. With the ambition to overcome regional inequalities and develop a unified action plan in the framework of the Union of South American Nations, Latin American countries have put together the Initiative for the Integration of Regional Infrastructure in South America. The plan consists of nine axes that cover the continent and the entire population and defined as multinational areas, including their production and commercial flows. The prioritization and justification of infrastructure in these axes and the smoothing of possible colliding interests require the development of models with various scopes, institutional needs, territorial coverage, and data requirements. The authors give examples of possible model philosophies that would solve the issues at three different levels: national level, multinational level, and binational level.

In this context, it is worthwhile to summarize the three examples given by the authors: (1) the Amazonian axis; (2) the Parana−Uruguay waterway, and the (3) Mercosur−Chile axis. Each of them has different integration challenges. The main obstacle in the Brazilian Amazonian axis is geographical and deals with the existence of the rainforest that cuts the axis into two different zones. On the other hand, the Parana—Uruguay waterway axis passes through six countries, and its development has huge coordination requirements. The river is still heavily underutilized, with approximately 80% of barges coming back empty. The Mercosur—Chile road axis, connecting Chile with Uruguay and Argentina, is the main road used to transport aluminum and copper from extraction sites to manufacturing plans and one of the most important RSCs in Latin America in terms of contribution to GDP. There is a clear need for developing several infrastructure projects along the corridor to increase its level of service. Specifically, there is a need for the development of intermodal terminals, gauge compatibility works, railway revitalization, and improvement and building of binational tunnels between Argentina and Chile.

The development of this expensive infrastructure requires sound decision-making assisted by models that take into consideration the integration of the three countries and the interactions between their economies. For the first axis, the authors propose the development of a model that includes the geographical limitations of the area, quantify the ability of the existing alternatives to redirect traffic, and calculate the feasibility to build new infrastructure. The example of the Mercosur—Chile axis is very interesting because policy makers want to consider the possibility of promoting the Chilean Pacific ports by strengthening the inland part network that connects Atlantic—Argentinean ports to the Pacific—Chilean ports. To do so, they need to check the feasibility of either building a new binational model between Chile and Argentina or improving the existing one that is prone to close down when weather conditions are bad. To inform this investment decision, the development of a model is necessary that compares the generalized costs of the two alternatives and helps identify the location of the new tunnel. A model is required to make predictions in long-term horizon frames by taking into account import, export, and final destination data. Models that address policies on multinational levels are usually broader in scope and do not require high levels of detail but are challenged by difficult coordination between numerous stakeholders. Scoping down the model to include the areas in close proximity of the tunnel and not the entire counties engages a smaller number of stakeholders and helps dealing with the aforementioned institutional issues. This approach, however, should be treated with caution because it could eliminate the information about wider regional impacts that may be important to consider.

One additional challenge faced by emerging economies is their evolution from centralized and controlled transport markets to more privatized and deregulated structures. This transitional process creates a rapid growth in the private sector, changes in the market structures, and a boost in foreign capital flows. Transport models are, therefore, required to capture this dynamically changing economic environment. To address this problem, Tapia and Sicra argue for the use of models that make interactions between supply and demand explicit. They give the example of the improvement of the Argentinean rail system, which, because of regulatory and infrastructural issues, has become downgraded. The first privatization of the network that was done in the early 90s was severely delayed because of regulatory issues and resulted in an overall deterioration of the infrastructure. The Argentinean crisis of 2002, the acquisition of railway lines by private companies that prioritize their products and make investments only in well-used links, decreased the rail share even further. The Argentinean government intends to reregulate the rail market with an open access policy to increase its level of service and its market share. In this context, the development of a model that captures both supply and demand is necessary. From the demand side, the model requires to capture mode choice by taking into consideration the modal shift generated by different levels of service and also the possible reaction of road operators who would probably change their pricing policies to attract more cargo. On the supply side, the model should capture pricing strategies for different levels of service as well as the interaction between the operators (who want to maximize their profits) and the public sector (who aims to maximize social benefit).

A model that includes supply and demand functions was used in Chapter 6 by Verhaeghe et al. for the particular case of a large archipelagic country, Indonesia. The emerging maritime economy of Indonesia requires strategic choices that will improve the efficiency of its large and complex network. Policy makers are asked, therefore, to make informed decisions for designing a national subsidized sea transport scheme, identify strategies for the reduction of transport costs, improve the country's international connectivity, and increase the accessibility of remote regions. The aforementioned goals set the requirements for the development of appropriate models. The authors propose a bilevel network approach that combines both demand and supply. Origin and destination tables of freight moved per year were used to represent the demand while a simulation of the network schedules and prices represented the supply. They use the model to get insights on the combination of policies such as (1) changes to the shipping fleet and its services, (2) port performance (evaluate turnaround time and handling costs), and (3) different network options (development of new corridors and maritime highways and potential new international port in the northeast). The philosophy of the model was built around a tour-based approach where they created freight—economy linkages by specifying the costs of the various components of the supply chain with a generalized cost approach where they considered door-to-door shipping rates (land transport, port-related costs, and line—haul costs), values of time, and other costs. They also set up a business cost model used to compute the unit cost for different combinations of shipment sizes, distance, waiting times, and vessel-related costs. The approach of the analysis can be transferred to different archipelagic countries that rely heavily on local, domestic, and international shipping services for their internal connectivity. Specific circumstances such as cost structures and wage levels, ship types, distribution of ownership over fleets, and the uneven distribution of the population and industry call for special care during transfer toward different contexts than the Indonesian, in particular, of the empirical findings. Several insights, however, should be broadly applicable. These include the crucial role of passenger and mixed-use ferries for industry, the possibility for local goods movements to piggyback on international lines, and the resulting necessity for joint optimization or alignment of schedules of these subsystems.

The dynamically changing environment of Greece, which is now emerging from its financial crisis, is presented in by Tsirimpa and Kapros, who describe the evolution of the Greek logistics market after the end of the Greek financial crisis. The crisis has shrunk the Greek GDP and abruptly changed both the logistics structures and the economic environment of the country. The Greek government proceeded to concession and privatize many parts of the road network, the railway network, and logistics facilities such as the ports of Piraeus and Thessaloniki, the most important logistics hubs of the country. The Greek authorities, through this privatization of the logistics infrastructure, were seeking to rationalize the national transport system and attract more transit traffic in the country. To cope with the aftermath of the crisis, the Greek Ministry of Transport developed the "New Transportation Plan of Greece," which, for the first time, included freight transport. The rapidly evolving economic environment requires the development of priority areas for future investments, which should be rational and well informed. To this end, the national plan includes models that predict the demand per transport mode as the one presented by Tsirimpa and Kapros. The authors incorporated the effects of the economic crisis in a questionnaire-based research in an aim to understand the decision-making framework of freight forwarders in Greece and developed a mode choice model that calculates the value of time for the different models. The paper, therefore, provides a typical narrative of how economic conditions translate into freight model requirements and model development.

## 4. Model specification

In emerging countries, senior policy makers are faced with urgent decisions on infrastructure development to cope with the changing economic environment. The lack of time and sufficient funding makes them ask for quick fixes such as the application of already developed advanced models for emerging countries. This solution can be effective as long as the models are properly adjusted to reflect the capabilities of the countries under question. The specification of models becomes a critical issue, however, when capabilities lag behind the needs. Currently, holistic approaches are in fashion, which include behavioral components, modules that explicitly model logistics approaches, and cross-border models of integrated supply chains. Where such data are not available, modelers have to resort to simplified transport models or alternative approaches to validate the models, triangulating different sources of data. Below, we discuss some salient examples presented in the book of model specifications typically found in emerging economies.

In Chapter 4, Havenga et al. propose a model specification approach that leverages existing data sources and addresses the policy questions of infrastructure backlogs in combination with economic and social challenges. In Chapter 8, the authors apply this approach to assist infrastructure decision-making in South Africa and India.

Specifically, they propose the development of a data-driven freight demand model. They follow a macroeconomic multiregional and multisectoral approach to develop an input–output (I-O) model used to forecast the demand and assess the impact of infrastructure development. Currently, statistical agencies aggregate data into production–consumption format, making it difficult for modelers to break them down into freight flows. The authors follow an approach where they first identify the main transport freight flows by creating a complete view of the country's economic activity (supply and demand) on the most detailed geographical and subsectoral level possible. They identify and merge different datasets for both private and public sources. The I-O model is then used as an input for a gravity model to quantify the freight flows between the geographical areas. In Chapter 8, the authors apply the approach in two countries, South Africa and India. One of the challenges for South Africa is to unlock logistics efficiencies to support economic growth, whereas India is faced with the challenge of creating infrastructure capacity to support its unprecedented growth rates. Both countries face socioeconomic challenges, extreme poverty, and significant spatial and income inequalities. South Africa has low economic development rates and an already existing infrastructure that is underutilized, whereas India suffers from high economic development rates not equally distributed and insufficient level of service from the existent infrastructure.

For South Africa, the authors apply the approach to inform infrastructure-related decisions that will increase rail share and improve the role of country's ports. They identify rail-friendly freight flows with the key characteristics of high-density goods and long-distances, including potential container loads. They identify corridors, combining dense, long-haul (end-to-end) traffic, and short-distance distribution. They use the model to make 3-year predictions and develop views on a mid-term and long-term rail market. In addition, for India, the authors identify modal shift and cost reduction opportunities that result from improved utilization of the transport system, including the seaports. Although there exists long-haul traffic that is feasible for modal shift, there is insufficient rail and waterway infrastructure.

Because still the majority of freight remains, policies to increase the efficiency of road transport remain important.

Chapter 10 presents a model adjusted to the needs in New Delhi, India, where the local authorities are trying to balance between accommodating the fast economic growth and improving the quality of life of citizens. Due to the growing urbanization and the increase in the economic activity, the city is facing an increase in pollution related to freight vehicles. The data available are insufficient for sophisticated models, however. Errampalli et al. develop a decision support system for air pollution reduction in the city of Delhi. They present a classical stepwise freight model, which has found broad application in many developing and developed countries. For the identification of freight flows within the city, they conduct extensive road surveys and use the results to quantify the supply and demand for freight transport. For traffic assignment and impact visualization, they apply a GIS platform. Although the approach is mathematically straightforward, it documents the challenging effort of building up new databases and a model that does not rely purely on forecasting past trends.

A global multimodal freight transport demand model is presented in Chapter 9 by Meersman et al. They address port and mode choice based on generalized costs and hinterland characteristics to understand the demand for the Belt and Road Initiative (BRI), in particular, the extent to which the rail connection from China to Europe can become a true competitor for sea transport. In recent years a debate has developed on the feasibility of the BRI and its effects on the local economies of the emerging countries it passes through. China promotes the BRI as a way to deal with the development inequalities between connected regions and wishes to decrease the amount of cargo that passes through the vulnerable Malacca straits. In addition, the Chinese government is focusing on the production of more high-valued commodities in the north western provinces and offshoring the production of low-value commodities to neighboring countries, which will be connected with China via the BRI. Models are needed to help establish which countries could invest in the BRI, based on forecasts of the demand for the different connection options. The model used describes the global transport chains and includes detail on the cost structures, freight services, and values applicable to the non-European countries on the considered rail link between China and Europe. In their paper, they present a model for mode and corridor selection; they discuss rail corridor investments needed to improve transit times and connection/accessibility. A calculation of generalized transport chain cost is used for comparing scenarios, modes, and hinterland origins and destinations.

In Chapter 11, Kourounioti et al. specify new time-of-day (TOD) models used in passenger transport that predict individuals' choices for every day commuting. They apply the TOD methodologies to predict daily import pick-up container patterns in a middle eastern port container terminal. They use aggregated data directly available from the Terminal Operation System (TOS) of the terminal and calculate the probability of an import container to be picked up by a truck. Model results will help operators optimize the daily planning of personnel and equipment, decrease waiting times at the gates, and decrease environmental pollution.

## 5. Data

Data availability for freight transport modeling has always been recognized as a challenge, especially when compared with passenger transport modeling. The collection of data that follows a shipment from the sender to the receiver is troublesome because of the confidentiality of the data. Companies are reluctant to share cost-related data because they are considered sensitive information and critical for their competitive advantage. The necessary data for the development of freight models are scattered over various locations and owned and collected by companies or by public authorities. This makes it difficult to merge transport, commodity, and economic sector data.

Emerging countries face similar issues; modelers have to deal with datasets that are incomplete and lack coherence. The available data are usually collected and maintained by public authorities, which possess limited data collection infrastructure, smaller data repositories, and whose employees do not have the necessary know—how and the ability to collect and maintain the datasets. In Chapter 1, Celebi gives the example of Turkey, where the only available data on freight flows are the road counts from the National Bureau of Road transport. This database is inconsistent, lacks detail, and has no information on commodity flows or loading factors, and thus, its applicability for the development of demand forecasts is limited. Both in emerging and developed countries, disaggregate data on shipment level are scarce because usually, they require expensive and time-consuming interviews. A small number of developed countries, such as Sweden, the Netherlands and Denmark, invest to collect commodity flow data. In general, as pointed out by Celebi in Chapter 1, emerging countries also suffer from a lack of standards and consistent methods for data collection.

Customs and waybill data are potentially useful sources of information that contain the commodity and weight of shipments, but additional data such as the origin and the destination must be retrieved from different sources (de Jong et al, 2016). The fusion of data from different sources presents an important opportunity for developing countries, which have to cope with the lack of structured and accurate databases.

In Chapter 5, Tapia et al. develop an approach that combines tax revenue data taken from public tax agencies to develop OD matrices and disaggregate mode choice models. The systematic collection of tax records in Brazil and Argentina permitted the development of well-structured and consistent databases on the economic interactions between individual companies. From these, the authors were able to derive individual flows. Specifically, they use electronic invoices (EIs) from the state of Rio Grande do Sul, Brazil, as well as consignment bills (CBs) from Argentina to develop OD matrices and disaggregated choice models. EIs include different levels of information per product type, but they all contain the same information about the shipper and the receiver of the goods (location, name, and ID), the transported product (type of the product, quantity, and value), and the taxes paid. The electronic CB data had the potential to be applied for more disaggregated mode choice models because it consists of records on agricultural goods that include the receiver, carrier, and shipper. The final compact database had information on which mode was chosen, the (estimated) size, date, origin, and destination. As the information on the nonchoses alternatives of the choice itself was missing, they had to combine data from other sources to recreate the full choice situation.

When discussing the possibility of using taxation data, anonymity should be ensured. Within the restriction of fiscal secrecy, there are several levels of details that the data can have. In the case that the data are provided in aggregated form (regional level, district cities, and provinces), then aggregated models, that is, OD matrices, can be created. If the data are provided in a disaggregated shipment level, then models reflecting individual choices such as mode choice can be developed. One important challenge is to ensure that tax authorities trust the transport modelers and are willing to share the data. The higher the trust and the cooperation developed between the tax authorities, the more detailed the information the authorities are willing to provide. Modelers should take into account the amount of work required from the tax authorities—they should be specific with data requests and aware of the limitations faced by the authorities. In all cases, data protection protocols are crucial to ensure that the data are used only for the intended purpose and by the authorized parties.

In Chapter 4, Havenga et al develop a model for more effective investment decisions that requires commodity and regional disaggregation. Havenga et al. propose a hybrid data collection approach that combines sources with various levels of detail, grouped both on geographical and commodity both for supply and demand. The data sourcing included existing sources that can be completely or partially related to freight, with an origin, destination, volume, or commodity attribute. They also managed to achieve spatial disaggregation for both supply and demand based on agricultural land uses, on the location of attraction production facilities, and on the population. This is done at a standardized district level, while all major air, sea, and land border posts are shown separately.

At a micro or firm disaggregate level, Kourounioti et al. in Chapter 11 apply data of a port container terminal and develop TOD-predictive choice models to help reduce uncertainties in the time of arrival of trucks. Container terminals generally apply truck appointment systems (TAS) to schedule and harmonize the arrival of trucks. In emerging countries, where low labor costs make automation less cost-efficient and truckers and terminals oppose the application of TAS, such predictive models can be beneficial. To address waiting times at the gates, the authors used data of TOS, in a case study for a Middle East terminal. The models explicitly capture the influence of container characteristics and day of the week at the distribution of drayage truck arrivals for importing container pick-ups. Data could be obtained only after a process of building trust with the owners, as also reported by Tapia in Chapter 6. Some databases were inaccurately filled, and it proved to be impossible to use certain fields of information, a problem also found by Celebi in Chapter 1. The developed models can be used alongside the TAS and provide terminal operators with tool for efficient day to day operational planning.

## 6. Conclusions

This chapter synthesizes the freight transport modeling issues presented in the different chapters of the book. We used the conceptual model presented in the introductory section to draw together the findings. Freight transport modeling in emerging countries is a challenge—these countries are experiencing rapid changes in economic development, together with changes in domestic and international trade flows. New policy priorities, changing governmental and regulatory structures, unstable development rates, varying speeds of technological diffusion, slow transitions from traditional to contemporary logistics systems, continuous changes in the competitive structure of logistics industries, and long-term uncertainties in market structure all are examples of characteristics that are specific to these economies. The application of models already developed in other counties is not always effective because these models may lack the representation of the above. This book has been developed around the four typical challenges for national-level freight modeling—institutional issues, specific model requirements, challenges in implementing modern model specifications, and a poor availability of data. The chapters explain these issues in more detail, develop approaches to solve these issues, and present related model applications in Greece, Indonesia, India, South Africa, and South America. The model examples can assist government authorities and industry in predicting the impacts of new policies and strategies.

The figure below summarizes these main challenges in emerging countries and presents the approaches applied to solve them Fig. 12.2.

In terms of institutional issues, the lack of representation and coordination among agencies, public authorities, and the private sector create confusion in determining the scope and the inputs and outputs of the freight models. The development of a national plan from the central government can provide guidance and ensure the coherence of models and policies. In

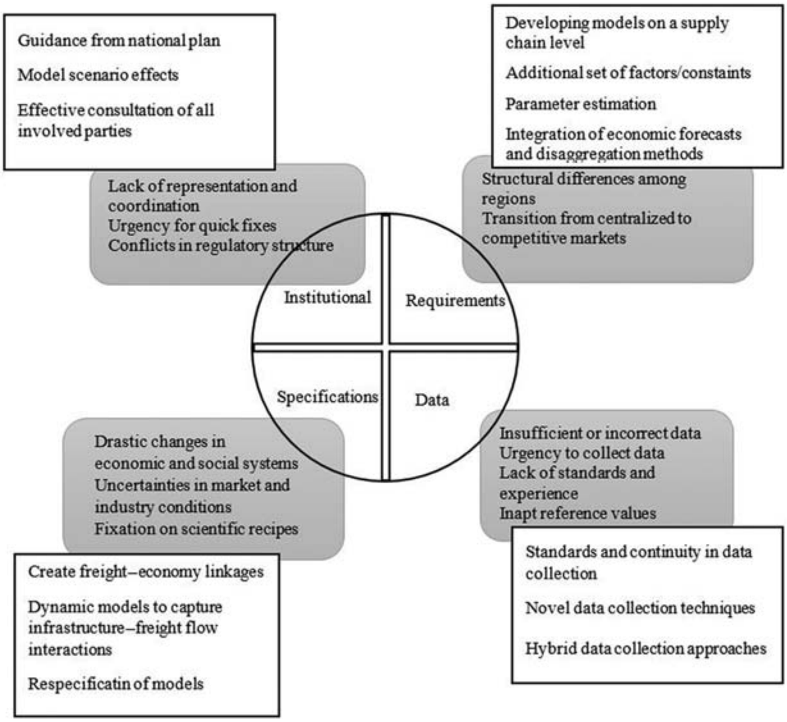


**FIGURE 12.2** Freight modeling issues in emerging countries.

solving institutional issues, the effective consultation of all engaged stakeholders will ensure the development of a realistic and correctly defined model where all actors' requirements are represented. Often, however, quick-fix strategies are required by senior policy makers who do not want to invest in expensive data collection and model development techniques.

In terms of requirements, a dominant problem appears to be that emerging countries are characterized by vast differences in the development state of the various regions, along with an uneven rate of development. For analyzing long-term impacts of structural changes in the production and logistics systems, novel approaches can be considered integrating economic and transport variables. New methods have been presented to simulate linkages between aggregate variables such as demand, regulations, uncertainty, investment strategies, and trade policies. The rapidly changing and complex economic environment can create many uncertainties, for example, in infrastructure development, rural development, R&D, regulation and trade policies, future demands in different sectors of the economy, and transportation costs. Freight transport models should account for these uncertainties.

Due to limited funding and the need for fast results, there is often a desire to apply the latest, refined models based on recent scientific literature. Ideally, for example, freight models should be able to predict future choices of freight transport actors, in response to policies. There is abundant literature on behavioral aspects of freight actors, and it is rapidly expanding, with a representation of logistics processes. In addition, sophisticated models are available that represent transport−economy linkages. However, often the lack of data and the limited experience of modelers lead to limited success and poor application of the results. Simplified models are then better suited to fulfill demands. Even in the case of poor data availability, however, there are several examples that show creativity in the use of data and modeling techniques.

Finally, the fourth pillar of issues is related to the limited availability of data. Emerging economies face serious issues related to data availability, organization, and standardization. The limited funding makes it difficult to develop accurate and complete datasets to understand freight flows to inform scenarios and the required infrastructure investments. The development of hybrid approaches that combine data from different private or public sources can function as a substitute and help verify and augment missing data. Several authors present approaches to overcome limitations in data availability through data fusion and triangulation. With these, even a seemingly patchy data infrastructure can prove to be of great value for freight model development.

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*Note*: Page numbers followed by "*f*" and "*t*" refer to figures and tables, respectively.

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# FREIGHT TRANSPORT
# MODELING IN EMERGING COUNTRIES

EDITED BY
IOANNA KOUROUNIOTI • LÓRÁNT TAVASSZY • HANNO FRIEDRICH

**Synthesizes successful applications of freight transport models for emerging countries, including decision-support models for freight flow forecasting, network planning and more.**

*Freight Transport Modeling in Emerging Countries* is set against the background of the unique transport-related policies, regulatory structures, logistics systems, and long-term uncertainties that determine the economic development of emerging countries. This book tackles these issues by examining decision-support models for forecasting freight flows at national and international level, modelling urban freight movements in megacities and port cities, using existing datasets to get information when data is not available, implementing policies related to the national and international movements of goods.

*Freight Transport Modeling in Emerging Countries* examines freight transport models developed in Turkey, South Africa, India and Chile. It provides a toolbox of successful freight transport model applications, alternative data collection methods and evaluation techniques for the development of future policies. The book offers solutions for issues related to the urban, national, and international transportation of goods and examines new advances of freight transport models, and data collection techniques and their applications.

## Key Features

- Includes a wide variety of opinions and approaches from subject matter experts around the world
- Utilizes a case-based approach
- Learning tools include chapter openers, end of chapter questions, a glossary and more

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