



Capacity to Grow

Transport Infrastructure Needs for Future Trade Growth



**Corporate Partnership Board
Report**

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Foreword

The work for this report was carried out in the context of a project initiated and funded by the International Transport Forum's Corporate Partnership Board (CPB). CPB projects are designed to enrich policy discussion with a business perspective. They are launched in areas where CPB member companies identify an emerging issue in transport policy or an innovation challenge to the transport system. Led by the ITF, work is carried out in a collaborative fashion in working groups consisting of CPB member companies, external experts and ITF staff.

Key authors include Jari Kauppila, Luis Martinez, Olaf Merk and Vincent Benezech of the International Transport Forum. The CPB companies involved in this project were COSCO, Michelin, PTV and Total. The project was coordinated by Philippe Crist and Sharon Masterson of the International Transport Forum.

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Executive summary

What we did

This report examines the consequences of **increased global trade on the world's transport infrastructure**. More complex international freight flows as a result of diversified global trade patterns will change capacity requirements and increasingly reshape global transport networks over the coming decades. Policy makers need to understand now how these forces are likely to play out in order to ensure adequate and timely investment into transport infrastructure that will continue to provide the backbone of global trade and economic development.

The analysis presented here builds on the award-winning International Freight Model of the International Transport Forum (ITF), which has been further refined to allow more precise projections to the year 2050. The main improvement was the inclusion in the model of congestion at terminal nodes and links as well as equilibrium assignment of freight. This now allows detailed analysis of the impact of congestion in international trade and a better assessment of future infrastructure needs.

What we found

The geographical composition of freight will change significantly between now and 2050. Trade in developing economies will grow around 1.5 times quicker than in developed economies. By 2050, the North Pacific route will **become the world's busiest freight route with** the biggest flow of goods. Significant growth will also take place in the Indian Ocean, the Mediterranean and the Caspian Sea corridors. Inland connections will also grow strongly, with freight volumes in intra-Asian trade multiplying by nearly seven times between 2010 and 2050. These projections rely on the assumption that there is no significant infrastructure bottleneck in the future to constrain growth.

Several uncertainties make projecting future trade growth challenging. Among the most significant is a potentially lower elasticity of trade to Gross Domestic Product (GDP) in the future that may follow from both cyclical and structural factors. As a result, freight estimates are likely to be revised downwards rather than upwards.

Taking into account uncertainties regarding trade elasticities and future utilisation rates of ports, the estimated capacity improvements currently foreseen will be sufficient enough to accommodate future traffic growth to 2030. Indeed, our projections show that only southern Asia needs to expand capacity beyond what planned or projected capacities are showing.

Hinterland connections will face the largest capacity challenges. These will be strained in Asia and Africa in particular, where estimated traffic growth is highest and the limited availability of surface freight infrastructure is becoming an impediment to trade activity. The need to expand capacity is particularly large for infrastructure close to ports or main consumption and production centres. This specific infrastructure will need to almost triple in Asia and Africa by 2050 to provide the performance levels seen in 2010.

What we recommend

Develop planning tools to adapt to uncertainties

Good port planning means planning for uncertainties. Timing is crucial and phasing in of terminal capacity necessary as a way to smoothen the lumpiness of new port infrastructure investment. The possibility to adapt to uncertainties is served by quick planning procedures and long term strategic planning. These strategic plans, which could look forward several decades, can identify new directions of development,

prioritise investments and identify future bottlenecks. Such plans could form the basis for land reservations and acquisitions for future port and corridor development.

Increase port capacity by optimising existing terminals

Good port planning can have an important impact on port performance, by optimising existing port capacity. Streamlining operations, through densification of port operations, spreading activities over the whole week 24 hours a day, and improved co-ordination between carriers and terminals - for example on stowage - are means of maximising capacity. Equipment upgrades, such as container cranes with the possibility of twin lifting and tandem lifting, could also speed up ship-to-shore operations and increase capacity without building new terminals.

Take a holistic planning approach to improving port capacity needs as part of the entire supply chain

The supply chain is as weak as the weakest link. Capacity can be improved by focusing on the efficiency of the whole supply chain, making use of best international practices such as truck appointment systems and intermodal hinterland transport options. Efficient operations are facilitated by smooth information exchange between the different port actors, for example via port community systems.

Use funding as a balancing tool in port capacity development

The emergence of port concessions is driven by the need for higher productivity. Smart concession design could help to achieve this. A way to find the right balance between terminal under-capacity and overcapacity could be strategic planning of port development and investment at the appropriate territorial level.

1. Introduction

In the flow of international trade, quality transport infrastructure plays a crucial role. Well-maintained and well-managed ports, highways, airports, rail links and related services connect trading partners and reduce transport costs. A 2004 study by the World Trade Organization found evidence that the quality of transport infrastructure has a significant impact on bilateral trade flows. Ultimately, efficient freight flows provide consumers with a wider choice at lower prices.

Poor quality or lack of infrastructure, on the other hand, increases transport costs, lengthens delivery times and can reduce economic growth palpably. Low quality infrastructure combined with remoteness are **important determinants of a country's ability to participate in the world economy.**

Providing a framework under which high-quality transport infrastructure can be developed is a core responsibility of governments. Countries therefore carry out assessments of the future infrastructure needs on a regular basis, and there are also some global assessments that review transport infrastructure needs for the longer term (such as OECD, 2012; OECD/IEA, 2013).

Much of the four-fold increase in international freight traffic projected by the International Transport Forum (ITF) involves goods exchange with world regions that currently have insufficient transport infrastructure (ITF/OECD, 2015). But how much infrastructure exactly is needed and where? Growth in freight will create challenges in these countries to develop and better manage infrastructure. On the other hand, many other regions are actively planning future capacity expansions and providing insight of where additional capacities are needed is crucial.

This project investigates capacity constraints in global ports and related hinterland connections (road and rail). It uses the ITF's global freight model to explore future transport infrastructure needs. The global freight model converts projected volumes of trade in monetary terms into tonne-units, differentiating by commodity class. It then optimises the allocation of the commodity flows across a global, multimodal transport network model, which contains detailed information about the speed of each mode in each link and inter-modal transfer times, as well as current and planned capacity.

We collected data on existing container port capacities and planned future capacity additions based on available surveys from maritime consultancies and in-house assessment on current state of the art of new port development projects. Our results show that, in most regions, projected capacity improvements at ports should suffice to tackle the increase in freight volumes. Hinterland connections, however, may hinder trade growth in some areas.

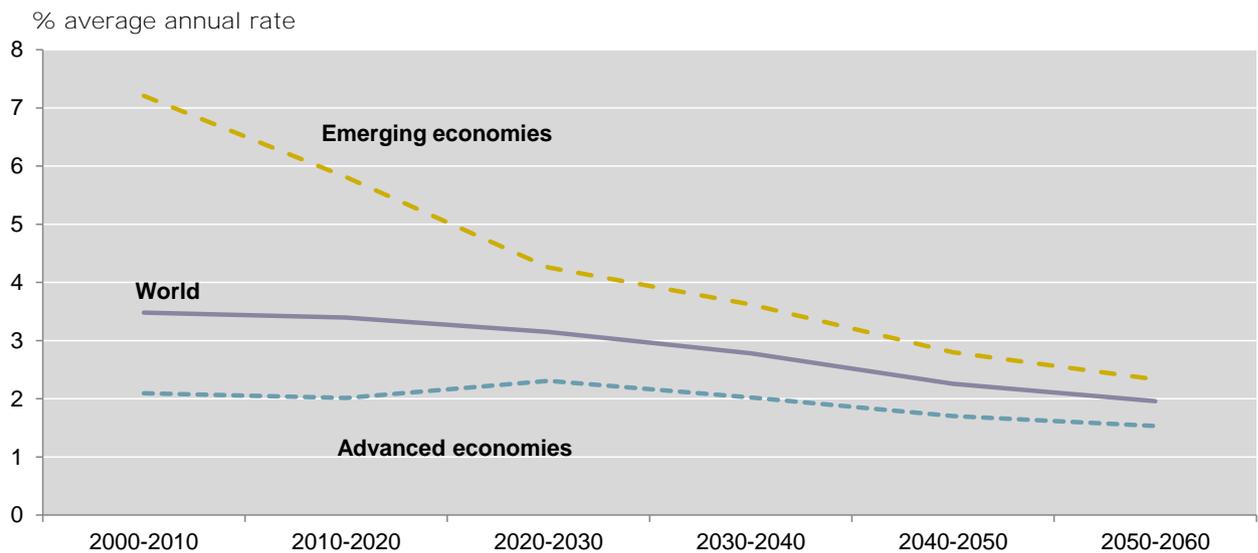
2. International trade: Looking forward to 2050

Freight transport, as a derived demand, directly depends on the trade of goods and raw materials. Changes in trade and manufacturing specialisation have significant effects on global supply chains and the associated freight movements. This chapter reviews the global trade and economic projections, which form the base of our analysis of future freight movements.

Gross Domestic Product (GDP) and trade scenarios in this report come from work carried out by the Economic Directorate of the OECD. This work is summarised in Johansson and Olaberia (2014). Box 1 presents the general methodology and characteristics of the models (see Chateau et al., 2014 and Johansson and Olaberria, 2014 for more details).

According to these projections, emerging economies will continue to drive global growth. However, the annual growth rate of the GDP will also decrease in these economies – from around 7% in the past 10 years to around 3% by 2050.

Figure 1. **Gross domestic product growth projections**



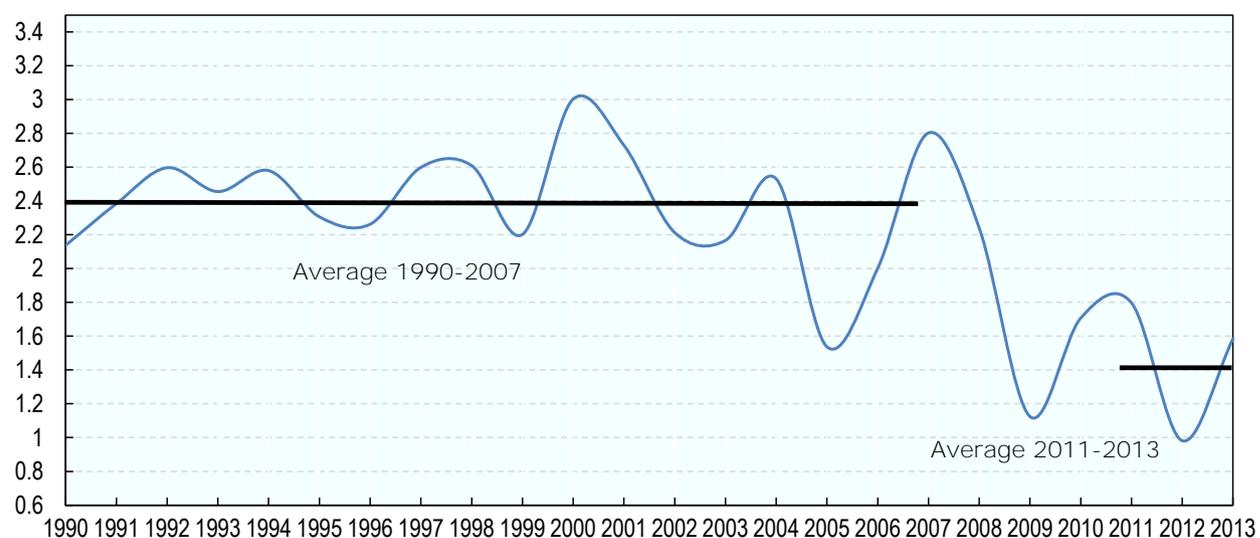
Source: Johansson and Olaberria, 2014.

Growth in trade is expected to outpace GDP growth over the next 40 years, although at a lower scale than during pre-crisis decades. World trade is estimated to grow at around 3.5% annually (compared with 6.9% over the period 1990-2007), implying a permanently lower elasticity of trade to the GDP of 1.4 and further declining to 1.2. This value is significantly lower than the 2.4 value of the 1990-2007 period (see Figure 2).

Several reasons, both cyclical and structural, have been put forward to explain the changes in trade elasticity (for discussion on trade elasticities, see Constantinescu et al., 2015; ECB, 2014). The cyclical reasons take root in the state of the global economy following the global crisis. The crisis hit advanced economies, and especially the EU, hardest and their contribution to trade elasticity fell sharply during the crisis. Investment, the most trade-intensive component of domestic demand, also suffered during the crisis. However, these are more the manifestation of a decline in the overall global activity rather than of changes in trade elasticity.

Other longer-term structural changes can explain the observed shift in elasticity. Emerging economies are moving up in the value chain resulting in an increase in domestic value added component of exports. The main contributors to world growth over the next half century will rely less on export-led growth than in the past decades. It also reflects that the intensity of fragmentation of global value chains is slowing down as there are likely physical limits on how much a product and task can be fragmented (Fontagné and Fouré, 2013). Indeed, there is evidence of consolidation of global supply chains since 2008, rather than fragmentation as previously observed.

Figure 2. **Trade elasticity to Gross Domestic Product**

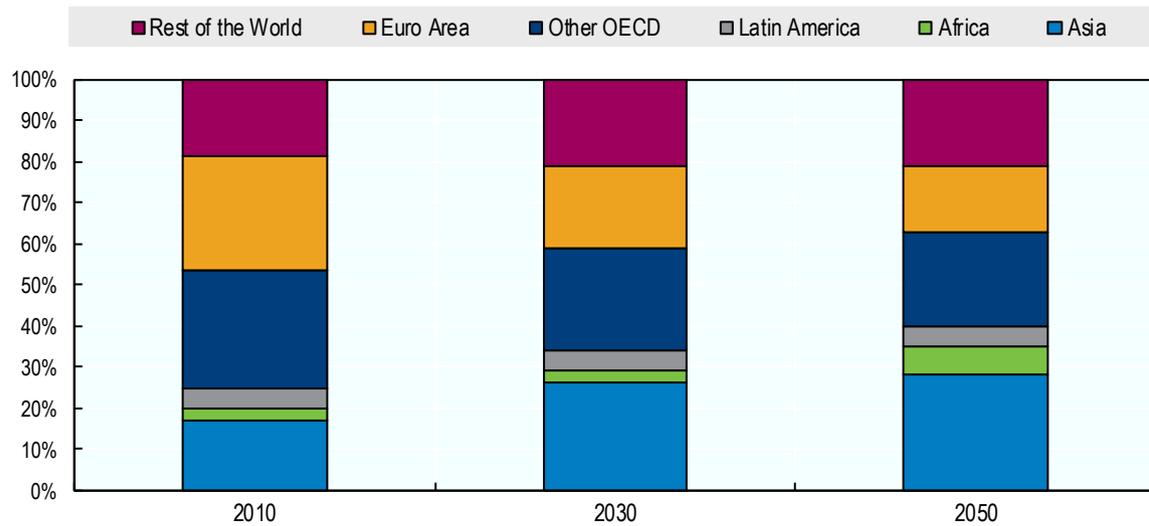


Source: ITF calculations based on World Bank and OECD data.

Still, in real terms, the value of international trade is estimated to grow by a factor of 3.4 by 2050. This impressive global growth figure goes together with two other significant changes, in the geographical patterns of trade and in the composition of trade.

Trade patterns are expected to shift geographically, illustrating the unequal distribution of income across world regions and changes in consumption structure and relative productivity. Asia and Africa will face the most substantial increases in trade shares, due to above average world economic growth, resulting in large market potential with low production costs. In parallel, trade within the euro area will perform less efficiently while some OECD countries will undergo a slight decrease in their trade share.

The evolution of the geographical structure of trade towards an increased role of emerging economies matches with the re-organisation of relative importance of different trading partners. Between 2012 and 2060, trade share in OECD countries area will halve, while it will more than double among non-OECD economies. Exports from Asian economies will increase from 17% in 2010 to 28% in 2030, while those from the euro area decrease from 28% to 20% in the same time (see Figure 3).

Figure 3. **Share of world exports, by region**

Chemicals, fuels, electronic devices, food and transport equipment account for a large share of world trade in value in 2010. Emerging and developing countries will experience sizeable increases in manufacturing market shares at the expense of OECD economies over the projection period. However, there will not be a total shift of industrial activities away from the OECD countries due to remaining large trade costs in specific industries.

Fast growing emerging economies will see a shift away from low-skilled manufacturing towards services and industry as a result of catching-up with income and living standards with more advanced economies. The resulting changes in consumption and domestic demand will influence their industrial structure. Agriculture and food trade is a significant component in world trade and it is projected to increase to 10% of total trade value by 2060. The United States and Asia will remain the dominant players with an increasing trade share in exports at the expense of Africa and Latin America. Agricultural exports, for example from the United States to China and Africa are to grow significantly over the projection period.

Box 1. Modelling framework for long-term global trade scenarios

The methodology used to design trade scenarios to 2060 combines two models. The long-run growth model in the OECD Economic Outlook (Johansson et al., 2013; OECD 2013) provides long-term projections for GDP, saving, investment and current accounts for OECD and non-OECD G20 countries, augmented with projections by Fouré et al. (2012) for other countries. The trade model is a version of MIRAGE, a multi-country, sectorial dynamic micro-founded model developed by the Centre d'Études Prospectives et d'Informations Internationales (CEPII) (Fontagné and Fouré, 2013; for details see Château et al., 2014). This computable general equilibrium (CGE) model analyses the global evolution of bilateral trade and sectorial specialisation and covers the world economy for 147 countries and 57 industries, aggregated into 26 regions and 25 sectors in the OECD framework.

The OECD designed trade scenarios to 2060 using a framework integrating long-term macro projections for the world economy with a sectorial trade model reproducing the key evidence characterising the driving forces of trade and specialisation of past trends. The objective is to provide long-term trade scenarios on the assumption that past trends will continue.

The aggregate projections, based on a growth model, were combined with the more detailed description of behaviour of consumers and firms provided by the CGE model. This combined model highlights **how countries'** specialisation is shaped by global trends (e.g. ageing, skill enhancement, capital investment, technology diffusion, etc.) and how structural and macro policies implemented in each country will affect future trade and specialisation patterns, taking into account inter-linkages across countries. This combination underlines the impact of both global trends and country-specific policies on future trade and specialisation patterns, acknowledging international spillovers. Trade projections are presented in value terms, in constant 2004 USD.

Source: Chateau et al. (2014); Johansson and Olaberria (2014).

3. International freight model: Four-fold growth projected

A refined modelling framework: Assessing capacity needs

To understand the future evolution of freight flows, the ITF at the OECD has developed a global freight model which converts trade flows in monetary terms into freight volumes. This section summarises the main step of the modelling approach. The complete workflow consists of four main steps, the last one being the new equilibrium assignment procedure (see Figure 4).

The regional aggregation of the underlying trade projections, while very convenient for economic modelling of trade activity, introduces significant uncertainties from a transport perspective as it does not allow a proper discretisation of the travel path used for different types of product. Therefore, in the first step trade volumes are disaggregated into trade flows between 333 centroids, each corresponding to an economic centre of activity (see Box 2).

The second and third step use econometric modelling to allocate trade between the different modes and transform trade in value into freight weight. These models, built with data from Eurostat and the Economic Commission for Latin America and the Caribbean, relate socio-economic, political and geographical variables to the choice of mode for each commodity and the ratio between value and weight. Martinez et al. (2015) detail the underlying databases, modelling assumptions and results.

In the original version of the model, the assignment of freight onto the network (the final step of our model) was based on an all-or-nothing algorithm. In effect, the freight transport network had unlimited capacity to absorb trade growth. The model did not consider transshipments at ports and freight was assigned to routes using the shortest path assignment. This resulted in unrealistic flows on certain infrastructure. It also did not take the specificities of ports into account: if one port was on the most direct route for a given origin-destination, it attracted all flows for this origin-destination even if its facilities for some commodities (e.g. liquid bulk) were limited.

Box 2. Centroids to represent freight origins and destinations

The OECD trade model gives results at a high level of aggregation, with 25 regions representing the world. Most regions regroup several countries, with the exception of large economies such as the United States or China. For our analysis of freight movement, we need to better understand the freight routes, which depend on the exact origin and destination within a country. For instance, freight routes from the east coast of the United States differ significantly from those starting on the west coast.

The freight model uses a discretised representation of the world, where centroid points represent the main centres of economic activity, whether in terms of production or consumption (or both), and the neighbouring region. An adapted p-median algorithm, determined by the UN, selects the centroids among all cities above 300 000 inhabitants in 2010. The objective function for the aggregation is based on the minimisation of a distance function with two components: GDP density and geographical distance.

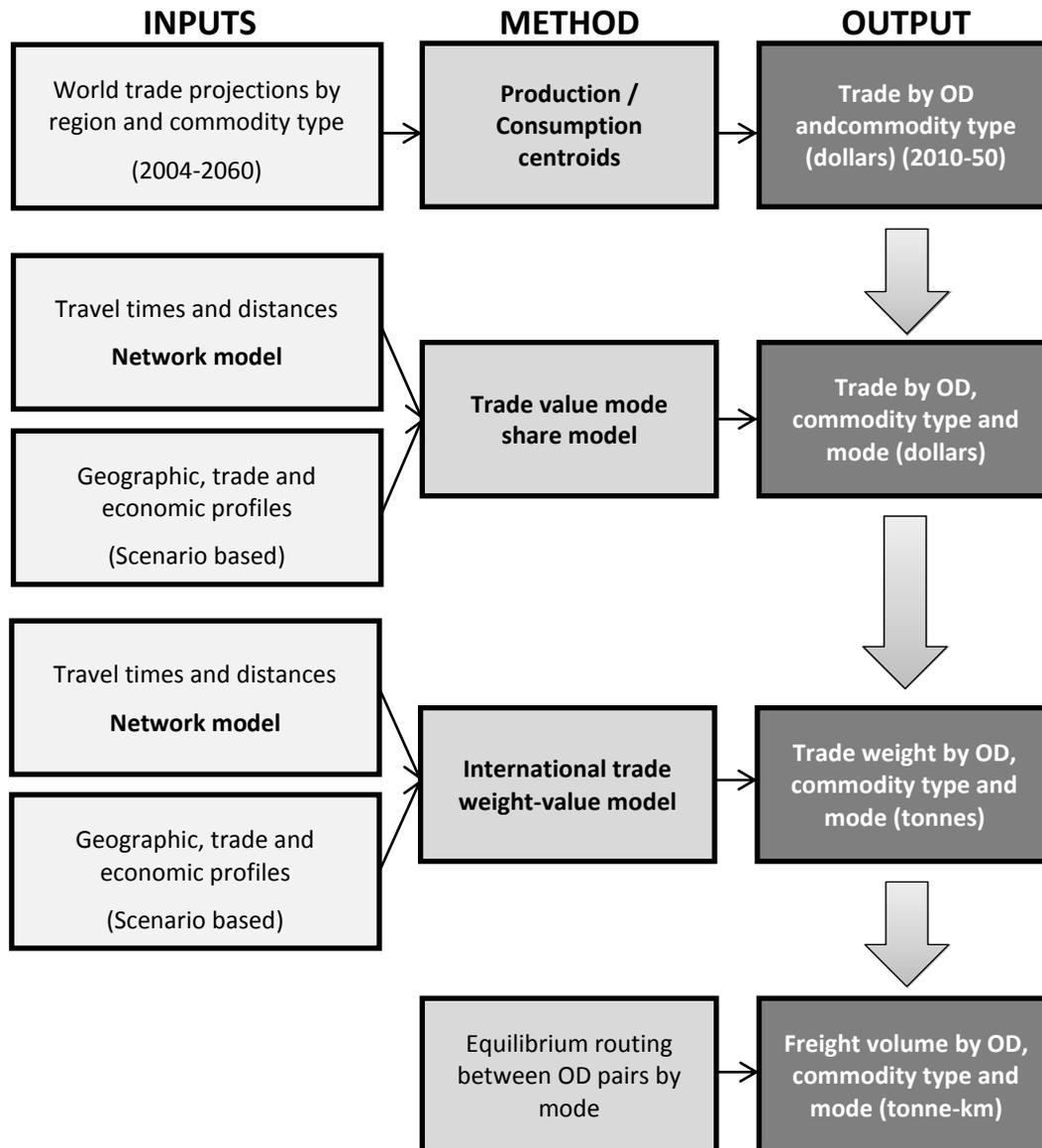
The procedure does not impose a predefined number of centroids. Rather, the centroids were selected with the conditions that two centroids within the same country cannot be closer than 500 km. With these premises the algorithm obtained a solution with 294 centroids, to which several other points were manually added to make up for some identified shortcomings (total 333). The trade flow between economic regions provided by the OECD study is then converted into trade flows between centroids, considering the regional GDP and its composition around each centroid as weights.

The growth projections of centroids are based on the growth rates at the country level obtained from the OECD 2013 economic projections. The share of trade flow between origin and destination (OD) pairs within the same country will be constant over time as the growth rates of centroids are at country level, and within a region. This calculation takes into consideration the local GDP composition obtained from the US Census at the state level and from the World Bank at the country level outside the US.

To overcome these challenges, the ITF revised the modelling framework to include the impact of capacity constraints and assess infrastructure needs for future trade. In this revision, detailed capacity information complements the description of the network and affects the assignment phase of the algorithm. The equilibrium assignment algorithm distributes freight flows (in weight) by commodity and mode among the different possible routes (see section on the freight transport network model below). The assignment is multi-modal: access to inter-modal facilities, such as ports or airports, also enter the assignment procedure. The domestic component of international freight is also studied: all paths contain a road, rail or inland waterways segment to transport the goods from the production center to the origin port/airport and from the destination port/airport to the consumption center.

Transshipment at large port facilities is also considered by including time penalties for low-frequency routes and assuming that route frequency increases with the size of the origin and destination ports. With this effect, containers shipped between two small ports can be transshipped at an intermediate larger port which has excess capacity. In effect, the attraction of each port as a transshipment facility is set as the overcapacity available, converted into time savings due to the high frequency of links with the port. This **behaviour in maritime movements produces a “hub-and-spoke” type of network, with the largest ports acting as hubs.**

Figure 4. Schematic description of the ITF international trade model



Freight transport network: A detailed representation

Assessing potential capacity constraints with precision is made possible within our modelling framework through the inclusion of a detailed global freight transport network based on data from Geographic Information Systems (GIS). This allows the model, although global, to describe network conditions at a detailed scale. Our main contribution is the consolidation and integration of all different modal networks into a single, routable freight network, and the association of capacity constraints to links and nodes.

The freight network comprises links and nodes for all four main modes: a global road network, containing the primary and secondary road networks (i.e. motorways, main roads and trunk roads); a rail network; an air network, including all commercial air links between international airports; a maritime network; and a global inland waterways system with navigable rivers (see Figure 5). In order to estimate travel times for

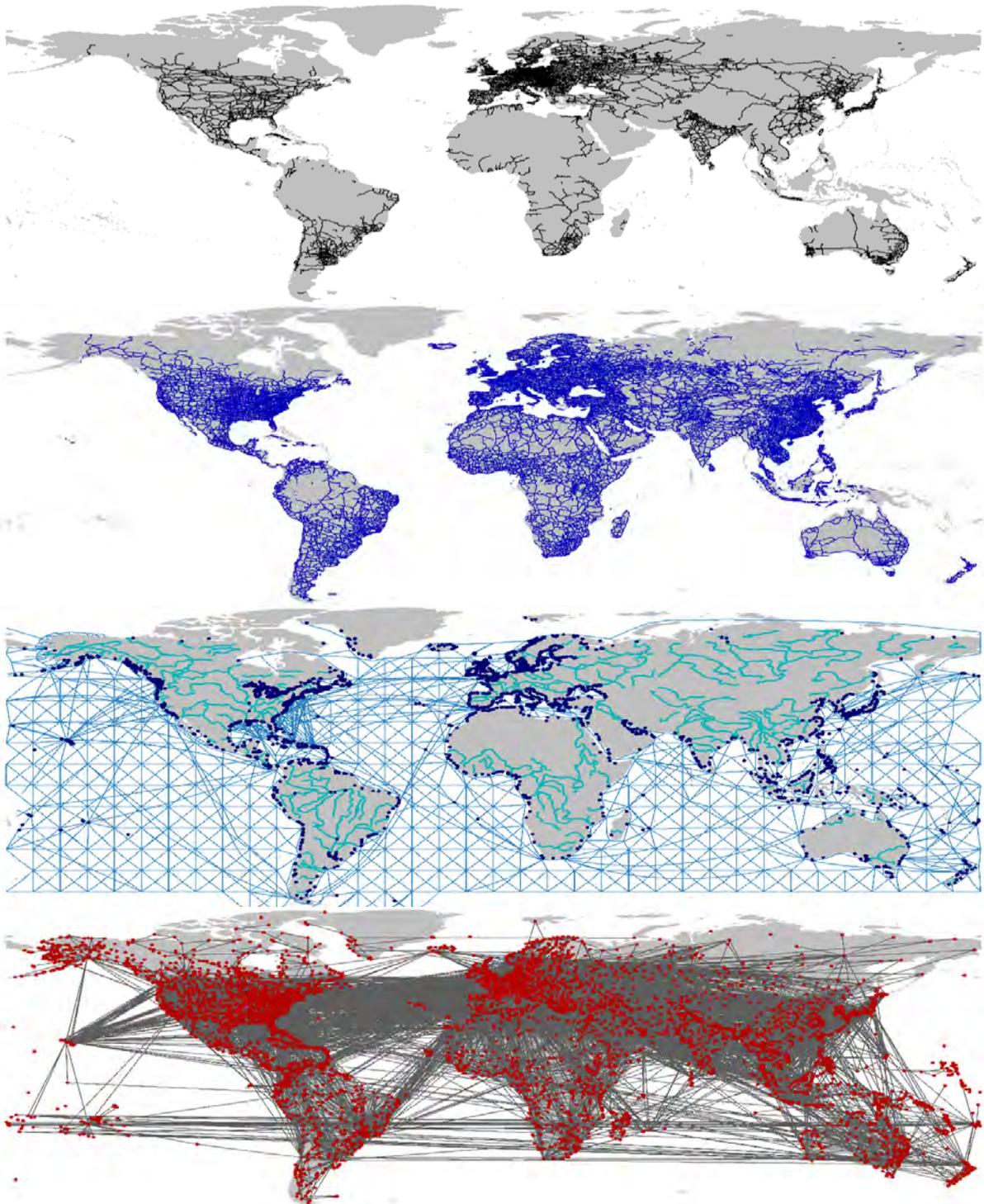
the different types of infrastructure, as well as dwelling times between transport modes, we use average speeds based on available information by region (see Annex, Tables A2 and A3).

GIS data for the global network model are available online:

- The road network information integrates two main sources: Global Roads Open Access Data Set (gROADS) (<http://sedac.ciesin.columbia.edu/data/set/groads-global-roads-open-access-v1>) and OpenStreetMap (www.openstreetmap.org).
- The rail network was collected from the Digital Chart of the World (DCW) (<http://www.princeton.edu/~geolib/gis/dcw.html>) project, integrated and updated with the OpenStreetMap data on rail lines and rail stations as intermodal points of connection between road and rail.
- The actual maritime routes are taken from the Global Shipping Lane Network data of Oak Ridge National Labs CTA Transportation Network Group (http://www.cta.ornl.gov/transnet/Intermodal_Network.html), which generates a routable network with actual travel times for different sea segments. We connect this network to ports, based on data from the latest World Port Index Database of the National Geospatial-Intelligence Agency (<http://msi.nga.mil/NGAPortal/MSI.portal>).
- The commercial air links between international airports were integrated using data from OpenFlights.org database on airports, commercial air links and airline companies (www.OpenFlights.org).
- The inland waterways network was obtained from the CIA World DataBank II (<https://www.evl.uic.edu/pape/data/WDB/>), and combined with information on the navigability for each river.

The different networks are consolidated into a single, routable network, and connected to the centroids using the road network and rail stations. The Annex presents statistics related to the number of links and the network length for each mode (see Table A1).

Figure 5. **Rail, road, sea (waterways) and air networks**
(top to bottom)



Port capacity: Extensive data collection

There are different ways to define terminal capacity. In general, this can be defined as the maximum volume that can be handled at a given terminal facility in a given time period. Physical limitation capacity is the volume achieved when there is 100% utilisation of the facility or its equipment. Design or theoretical capacity assumes that equipment is utilised to the maximum extent that is technically advisable, so allowing for maintenance downtime. What we want to capture in this study is the commercial capacity, which is the maximum throughput of a terminal that can be achieved at the quality of service that the terminal operator would like to guarantee to its customers (Drewry, 2010).

To assess future port infrastructure needs, the ITF built a detailed database of current port capacity, along with planned capacity increases. The data come from the combination of several sources: Drewry (2014), Dynamar (2015), OSC (2012a, 2012b, 2012c) and Clarkson port database. These publications are complemented with data from national port authorities for the United States, Australia, New-Zealand and Brazil, as well as data from Eurostat for European ports. To account for some possible inconsistencies in the way these reports define capacity, we will carry out also a sensitivity analysis on the utilisation rate of ports.

For each port, we differentiate five types of cargo: containerised cargo, liquid bulk, dry bulk, break bulk and Ro/Ro. Each commodity is associated to one cargo type. The capacity figures introduced in the model are in TEU for containerised goods and in tonnes for non-containerised goods. Table A5 in Annex summarises the capacity by type of cargo and world region. It also shows the coverage of our data collection exercise, which focuses mainly on large ports (above 500 MTEU) along with ports where data is freely available. The global coverage is 75% in terms of TEU, with numbers ranging from 53% in Scandinavia, where small and medium ports make the bulk of port capacity, to close to 100% in regions of the world such as North America or China where large ports are predominant for international freight movements.

There are already numerous plans for port expansion. The Global Container Terminal Operators from Drewry (2014) as well as reports from Ocean Shipping Consultant (2012b, 2012c) and Dynamar (2015) forecast port capacity developments until 2025-2030 based on announced expansions in the coming decade. Each report has a different geographical reach and detail level. These data form our baseline for the port capacity increase for all types of cargo up to 2030 (see Table A4 in Annex).

Road and rail capacity: Adding constraints

Road capacity, especially that of highway, is a very well documented subject. The Highway Capacity Manual (HCM, 2010) constitutes a reference in the field, giving simplified formulas for the capacity of a link depending on the number of lanes. The road network data categorises road links into seven groups, each group being assigned a fixed number of lanes and thus capacity (see Table 1).

To apply these capacity constraints to our model, we make two additional assumptions. First, we set the maximum share of heavy vehicles in the overall traffic up to 25%. Second, there is a single average truck load by commodity, which takes account of empty movements. These assumptions come from a rough assessment of the mix of traffic in the United States (FHWA 2009) but can easily be refined (by region or even link) in subsequent versions of the model.

Table 1. **Statistical and capacity characterisation of road network**

| Road type | No. of lanes | No. of links | Network length (km) | Hourly capacity per lane (vehicles/hour) | Hourly heavy vehicles capacity (vehicles/hour) | Yearly heavy vehicles capacity (vehicles/year) |
|-------------------|--------------|--------------|---------------------|--|--|--|
| Beltway | 2 | 1 228 | 9 553 | 1 600 | 3 520 | 1 284 800 |
| Bypass | 1 | 30 | 189 | 1 400 | 1 540 | 562 100 |
| Major highway | 3 | 37 570 | 689 206 | 2 000 | 6 600 | 2 409 000 |
| Road | 1 | 27 906 | 968 172 | 1 200 | 1 320 | 481 800 |
| Secondary highway | 2 | 34 054 | 963 477 | 2 000 | 4 400 | 1 606 000 |
| Track | 1 | 80 | 9 396 | 800 | 880 | 321 200 |
| Unknown | 1 | 56 026 | 2 222 592 | 600 | 660 | 240 900 |

Rail capacity depends on several attributes of the rail infrastructure, the mix of traffic between passenger and freight and the rules of priority which apply. For the global freight model, which works with a very large scale, we apply simple rules coming from the Multimodal corridor and capacity analysis manual (Cambridge Systematics, 1998). The manual defines capacity for rail infrastructure at a very high level using only a few attributes of the infrastructure, such as the number of tracks, the availability of Automatic Block Signal system or the level of centralisation of traffic control.

Table 2. **Rail line engineering capacity**

| Number of tracks | Automatic Block Signal System | | Traffic Control Centralised | |
|------------------|-------------------------------|-------------------------------------|-----------------------------|-------------------------------------|
| | Trains per day * | Gross tonnes per year ** (millions) | Trains per day * | Gross tonnes per year ** (millions) |
| Single | 40 | 62 | 60 | 93 |
| Double | 120 | 186 | 160 | 250 |

*Total both directions

**Gross tonnes per route mile, total both directions

Source: Cambridge Systematics (1998).

The rail network in the global freight network model does not contain all the attributes needed to apply the formulas in the Manual. However, it includes an attribute regarding the quality of the infrastructure, a single figure ranging from four to ten. We connected this level of quality to the availability of Automated Block Signal System and the number of tracks. For instance, rail tracks of level four in the network are assigned to high-speed rail with at least double tracks. Table 3 gives the correspondence between the quality of the infrastructure and the yearly container capacity.

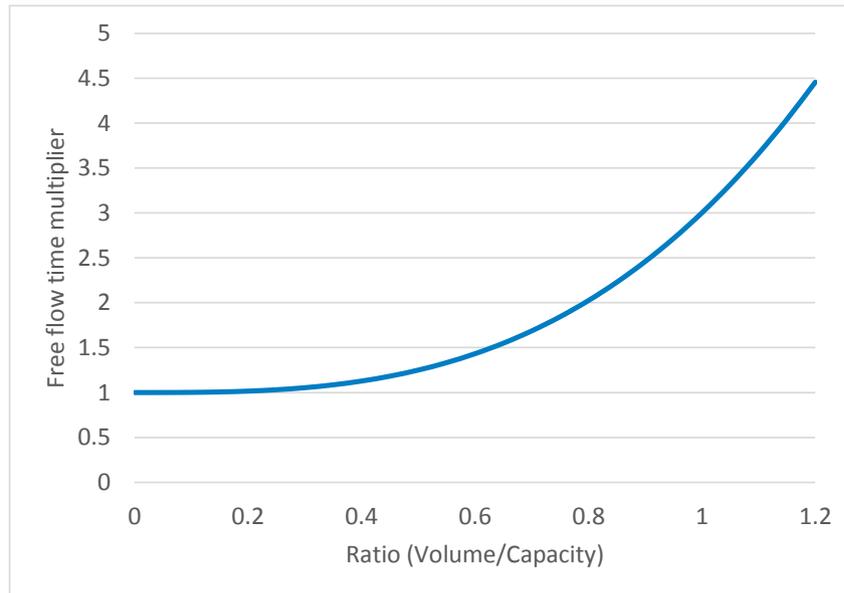
Table 3. Rail infrastructure classification and freight capacity estimation

| Scale rank code | Class characterisation | Double Track | Automatic Block Signal System | Traffic Control Centralised | Network length (km) | Yearly container capacity (TEU/year) |
|-----------------|--|--------------|-------------------------------|-----------------------------|---------------------|--------------------------------------|
| 4 | High speed rail tracks | Yes | Yes | Yes | 6 200 | 16 666 667 |
| 5 | High performance rail tracks (speed \geq 120 km/h) | Yes | Yes | Yes | 23 000 | 16 666 667 |
| 6 | High capacity tracks | Yes | Yes | No | 85 000 | 12 400 000 |
| 7 | Conventional tracks with traffic control centralised | No | Yes | Yes | 59 447 | 6 200 000 |
| 8 | Conventional tracks with no traffic control centralised | No | Yes | No | 182 842 | 4 133 333 |
| 9 | Conventional tracks with no automatic safety systems (speed \geq 50km/h) | No | No | No | 256 618 | 1 333 333 |
| 10 | Conventional tracks with no automatic safety systems (speed < 50km/h) | No | No | No | 391 292 | 1 333 333 |

Assessing capacity constraints: Delay functions and equilibrium assignment

There are many possible ways to render the impact of congestion on traffic or assignment in a model. The most appropriate methodology depends on the level of aggregation and the outputs expected from the model. The global freight model introduces delay functions on links and at nodes where capacity is studied. For this report, the analysis is limited to sea ports, road and rail, which are the main potential bottlenecks of freight movements. Indeed, capacity constraints at airports and rail stations result more from passenger rather than freight movements.

A delay function describes the relationship between traffic and speed on one road section or at one node. The most common family of delay functions are called BPR functions, from the name Bureau of Public Roads of the US administration which first introduced them in their models. These functions have a common, two-stage behaviour, visible in Figure 6. Travel or transfer time stays similar to the free-flow value when traffic volume is considerably smaller than capacity and increases as traffic nears and then exceeds capacity. The function is convex to reflect the more-than-linear effect of traffic volume on travel time.

Figure 6. **Delay function used in the study**

In the case of ports, the behaviour of the mathematical function reflects the common observation that, as a terminal approaches 100% utilisation, it is increasingly difficult to keep similar service levels. When berth occupancy exceeds 75%, vessel queuing becomes an issue and worsens exponentially there after. Although occasional utilisation rates higher than 100% can be accommodated, this cannot be sustained for long periods. So, when throughput exceeds capacity an additional time penalty avoids over-capacity in ports.

This type of function suffers from many drawbacks when approaching congestion from a micro-level but applies very well for macro-analysis, as is the case here. With the introduction of delay functions for many links and nodes, shortest paths become dependent on the traffic volume. This introduces a feedback loop between the route choice and the travel time components of the model. Cargo volumes increase the delays at nodes and links, diverting traffic from these elements, modifying once again travel speeds, and so on. Iterating this procedure until an equilibrium appears yields the final assignment results. Contrary to the unconstrained model, several paths link each origin-destination pair at the equilibrium. The model outputs the freight flow by cargo type at each node and link at the end of the assignment, allowing the estimation of the final travel times and delay functions, as well as freight volumes at links and nodes.

Box 3. **Equilibrium assignment procedure**

Under a shortest-path assignment procedure, for instance in the unconstrained version of the ITF global freight model, all traffic from one origin-destination pair goes through the same, shortest route. In some cases, the resulting flows can exceed the capacity of the arcs they go through.

Equilibrium assignment procedures answer this problem. Such procedures use an iterative assignment process to allocate flows between the different possible itineraries until all have similar travel time when accounting for congestion. This state is called a Wardrop equilibrium, and is the transportation equivalent of the more general Nash equilibrium.

4. International trade-related freight and capacity needs

Benchmark of 2010 freight volumes: Analysis of the quality of the model

The ITF model yields results for mode totals, in tonnes and tonne-kilometres, very close to data provided in other sources. The model is able to reproduce adequately current aggregate market behavior. This suggests that the mode choice and value-to-weight components perform well. Table 4 shows a benchmark of the model estimates against available data for the base year 2010.

Table 4. **Comparison of model results for the baseline 2010 statistics**

| Variable | Model estimates | Available statistics | Source |
|---|-----------------|----------------------|-------------------------------------|
| Maritime international trade volume (million tonnes) | 8 326 | 8 408 | UNCTAD review of Maritime Transport |
| Air international trade volume (million tonnes) | 31 | 32 | ICAO |
| Maritime international trade related freight (billion tonne-km) | 71 064 | 65 599 | UNCTAD Review of Maritime Transport |
| Air international trade related freight (billion tonne-km) | 172 | 158 | ICAO |
| Inland waterways international trade related freight (billion tonne-km) * | 2 298 | 2 931 | ITF |
| World port container traffic (million TEU) ** | 534 | 542 | World Bank |
| World airport international freight traffic*** (million tons) | 60 | 61 | ACI (2015 value) |

Sources: UNCTAD Review of Maritime Transport 2012; ICAO Annual Report of the Council, 2012; International Transport Forum (ITF), OECDStats; World Bank data; ACI monthly traffic data

* The source does not differentiate from domestic and international trade related freight traffic

** The source of World Bank does not differentiate national from international container traffic

*** The ACI data only includes ACI member airports (770 airports)

We also assess the port traffic by sea region in TEU and the share of weight of the different types of cargo (see Table 5). The benchmark values come from the World Bank (2010). The World Bank give country totals, regardless of the maritime façade. We split these numbers by sea regions using the proportions of our modelling exercise to obtain comparable values.

Table 5. **Characterisation of port traffic activity by sea region in 2010**

| Sea Area | World Bank 2010 (million TEU) | Model 2010 (million TEU) | Total tonnage (million tonnes) | Container traffic (%) | Dry bulk (%) | Liquid bulk (%) | Break bulk (%) | Ro/Ro (%) |
|--------------------------------|-------------------------------|--------------------------|--------------------------------|-----------------------|--------------|-----------------|----------------|-----------|
| North West Europe | 53.89 | 59.55 | 2 161 | 42 | 14 | 12 | 22 | 10 |
| Greater China | 153.99 | 139.50 | 3 119 | 66 | 10 | 8 | 14 | 2 |
| South East Asia | 74.02 | 87.06 | 2 368 | 55 | 11 | 13 | 17 | 3 |
| North Asia | 37.24 | 48.30 | 1 578 | 46 | 14 | 18 | 16 | 6 |
| East Coast North America | 22.44 | 21.26 | 911 | 36 | 15 | 19 | 20 | 10 |
| West Coast North America | 23.05 | 23.42 | 772 | 45 | 11 | 13 | 24 | 8 |
| West Mediterranean | 23.22 | 24.83 | 860 | 48 | 10 | 16 | 14 | 12 |
| East Africa | 6.58 | 5.98 | 247 | 40 | 9 | 33 | 14 | 3 |
| South Asia | 17.32 | 18.47 | 691 | 42 | 20 | 16 | 20 | 3 |
| East Mediterranean & Black Sea | 11.72 | 13.33 | 1 037 | 20 | 19 | 24 | 28 | 9 |
| Middle East | 30.09 | 25.17 | 1 167 | 35 | 10 | 39 | 13 | 3 |
| Gulf Coast North America | 6.73 | 7.58 | 410 | 26 | 14 | 21 | 29 | 10 |
| Scandinavia & Baltic | 7.82 | 8.33 | 602 | 20 | 14 | 11 | 36 | 19 |
| Southern Africa | 3.91 | 4.12 | 235 | 28 | 29 | 18 | 18 | 7 |
| Oceania | 9.77 | 8.90 | 399 | 36 | 29 | 9 | 21 | 5 |
| Central America / Caribbean | 17.31 | 9.36 | 377 | 42 | 17 | 20 | 17 | 5 |
| East Coast South America | 10.84 | 9.12 | 598 | 25 | 32 | 18 | 20 | 5 |
| West Africa | 3.79 | 4.20 | 225 | 30 | 18 | 30 | 17 | 5 |
| North Africa | 8.91 | 8.54 | 265 | 42 | 17 | 15 | 19 | 7 |
| West Coast South America | 6.62 | 5.74 | 208 | 47 | 22 | 14 | 13 | 4 |

The spatial discretisation presents a good adjustment to container traffic movements. It only underestimates the Central America / Caribbean transshipment traffic around the Panama Canal. The values show a dominance of container traffic, especially in China and South East Asia, due to the high volumes of exports of manufactured products. Liquid bulk represent a large share of port movements in locations with large crude and refined oil production, especially in the Middle East and East Africa. Dry bulk becomes more relevant in mining regions such as South Africa, Australia and eastern South America.

The locations of transshipments (see Table 6) are concentrated around China, Southeast Asia and the areas with main world canals. We also observe some regional transshipment. For instance, the largest European ports such as Rotterdam, Antwerp or Hambourg have a share of transshipment close to 20%. Model results are in line with real data on transshipment patterns (Nottebock et al., 2014).

Table 6. **Model estimates of transshipment share of container traffic in 2010**

| Sea Area | Transshipment share of container traffic (%) |
|--------------------------------|--|
| North West Europe | 8 |
| Greater China | 40 |
| Southeast Asia | 24 |
| North Asia | 8 |
| East Coast North America | 2 |
| West Coast North America | 0 |
| West Mediterranean | 5 |
| East Africa | 31 |
| South Asia | 7 |
| East Mediterranean & Black Sea | 10 |
| Middle East | 33 |
| Gulf Coast North America | 0 |
| Scandinavia & Baltic | 2 |
| Southern Africa | 15 |
| Oceania | 2 |
| Central America / Caribbean | 25 |
| East Coast South America | 7 |
| West Africa | 0 |
| North Africa | 39 |
| West Coast South America | 5 |

The future of freight flows: Significant changes in the geographical composition of trade

The expected growth in trade translates into freight volumes (in tonne-kilometres) growing by 4.2% annually between 2015 and 2030, and 3.3% after that year. In 2050, freight transport represents more than 385 billion tonne-kilometres, or 4.3 times the 2010 figure. These results can be further refined according to three axes: modal split, geographical patterns and commodity composition.

In terms of modal split, we do not predict any major shift. Maritime transport will remain the main mode for international trade, accounting for about 85% of the total volume in 2010, and around 83% in 2050. When excluding the domestic component of international trade, sea accounts for 95% of total tonne-kilometres. But adoption of more proactive policies related to climate change (including the necessary measures at investment, pricing and managerial levels) could have a strong impact in the split between land modes. Those are not included in the computations and results presented in this report.

While the modal split does not evolve much, significant changes will take place in the geographical composition of freight. Figure 7 shows the spatial location of freight corridors and their respective freight volumes in 2010, 2030 and 2050. The evolution of freight volumes is significantly stronger in maritime routes and inland connections in Asia: intra-Asian trade will multiply by nearly seven between 2010 and 2050, compared to tripling for intra-European trade. As a consequence, freight in relation with Asia comes

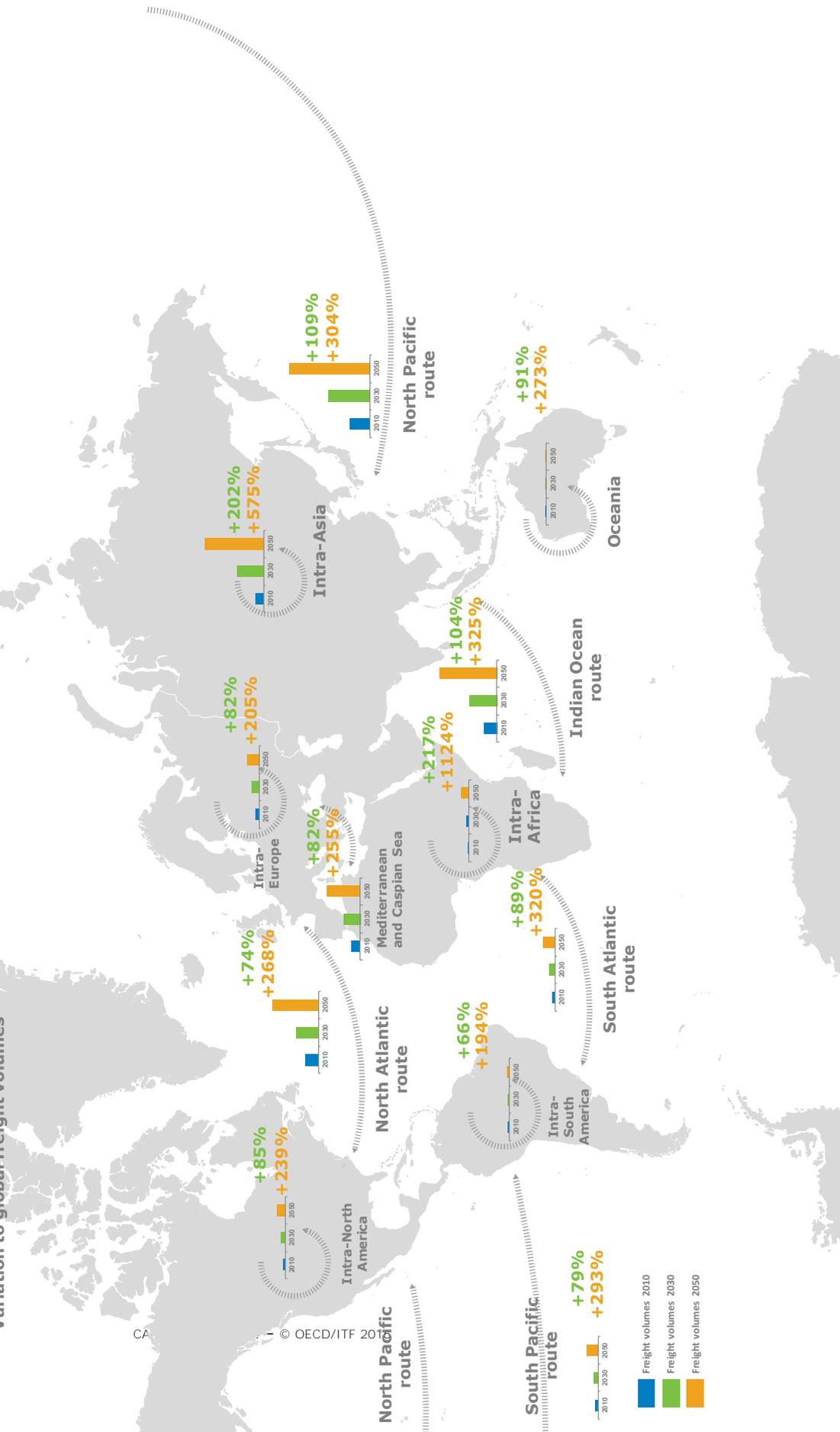
to represent 53% of freight volumes in 2030, up from 44% in 2010, while the share represented by European freight decreases in the same period.

The traditional trade routes between developed economies will grow relatively slowly, whereas the growth of the trade corridors connecting emerging economies will average 17% annually. By 2050, the transport corridor between the United States and China will be subject to the highest flow of goods (in both directions). Significant growth will also take place in the Indian Ocean and Mediterranean and Caspian Sea corridors. This reflects the shift of the economic centre of gravity towards Asia. Despite the slow growth of the intra-European corridor (1.5% annually), it will still remain, in absolute terms, as one of the most active freight transport corridors in the world.

The changes in the geographical patterns of global freight go together with a shift in the type of commodities being exchanged, especially in developing countries. The value density of the goods transported from Africa will increase by 52% by 2050, exceeding the value density of imports from the European Economic Area (EEA) and Turkey, North America and South America. China and South Korea are predicted to be the leading exporters of high value density products such as electronic components and mobile phones. On the other hand, the United States and Latin America will observe 30%-40% decline in value-weight ratio of exports, primarily due to an increased share of bulk goods in exports.

Rising food demand, especially in Asia and Africa, will prompt a massive increase in food transport volumes. Agricultural products and food imports in China and Africa will grow exponentially, and by 2050 China and Africa will receive almost 32% and 19% of the total world food transport respectively (in tonne-kilometres). On the other hand, the United States will keep its position as the major food supplier in the world and, by 2050, almost 38% of the food transported (in tonne-kilometres) will originate from the United States, followed by Europe (11%) and Brazil (8%), according to our projections.

Figure 7. **International freight in tonne-kilometers by corridor: 2010, 2030, 2050**



Corridors: 1) North America; 2) North Atlantic; 3) Europe; 4) Mediterranean and Caspian Sea; 5) Asia; 6) North Pacific; 7) South Pacific; 8) South America; 9) South Atlantic; 10) Africa; 11) Indian Ocean; 12) Oceania. Surface freight in international trade: Towards a continued reliance on roads

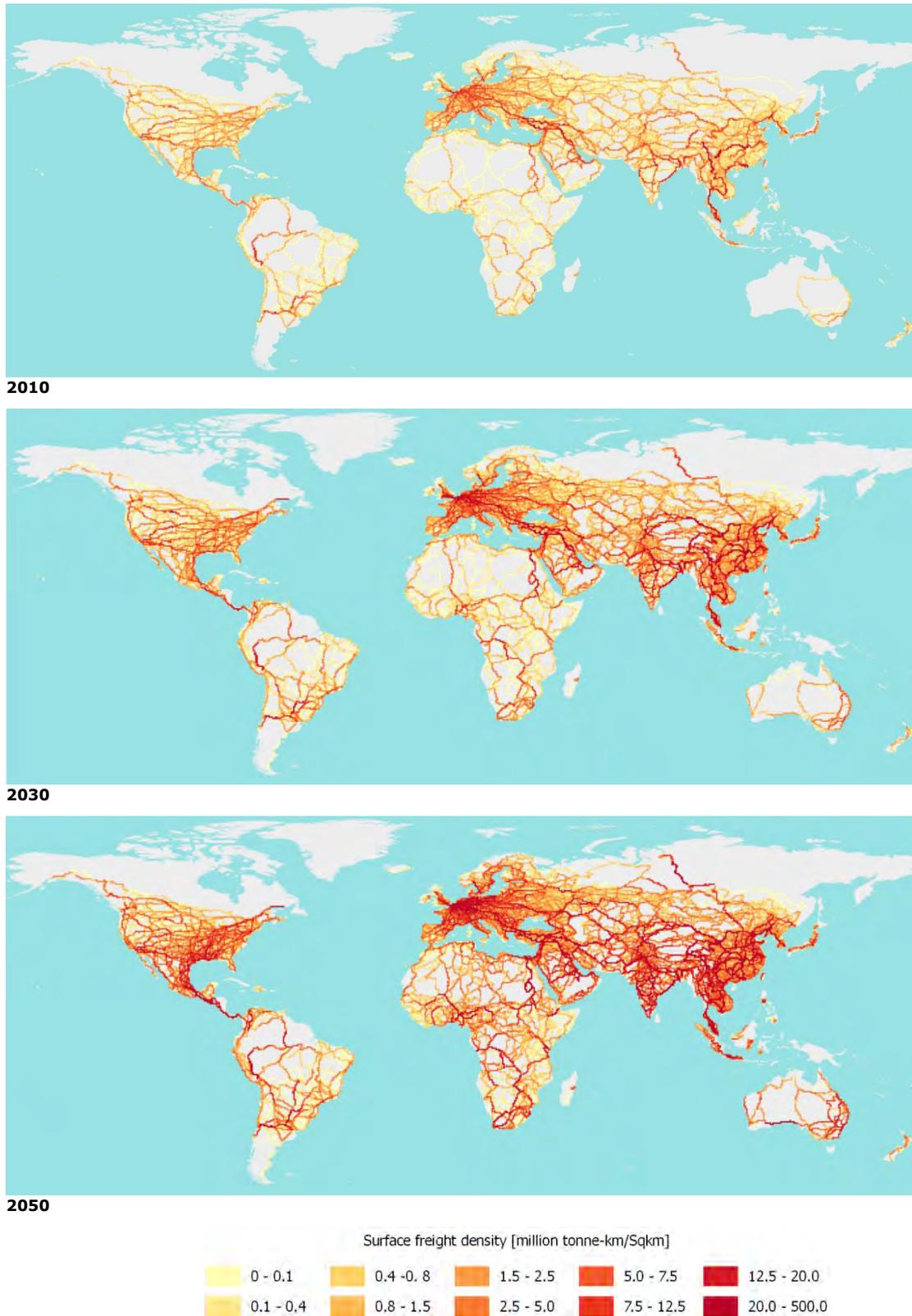
Surface freight (including inland waterways) from the international trade of goods is expected to grow faster than maritime, from 19 284 billion tonne-kilometres in 2010 to 104 777 billion tonne-kilometres in 2050 (443% increase). Significant growth will especially take place in Asia, where surface freight volumes are projected to grow by over 500% by 2050. Intra-African volumes will grow even more significantly (over 1000%), although from much lower initial levels.

The relative share of the different surface modes will depend on the infrastructure availability in the different corridors, environmental constraints and congestion of especially road transport. In 2010, rail accounted for 16% of total tonne-kms and inland waterways 12% of the total. Road transport is clearly dominant. Future policies may change this picture or preserve the dominance of road transport. In some regions, especially in Asia and Africa, road transport may even increase if nothing is done, since no rail nor waterway infrastructure is available in the areas where freight is projected to increase. The share of road transport in overall international trade related transport volumes in coastal countries is expected to remain constant around 4% while road freight transport will constitute almost 12% of the international freight transport in landlocked countries (up from 8%).

Figure 8 presents the spatial density of the surface freight linked to international trade. Some corridors in China, Southeast Asia and Europe become significantly congested. Congestion in South America and Africa emerges around 2030 and becomes more evident in 2050. In many respects, the picture in developed economies will, in 2030 or 2050, resemble, in terms of intensity, that observed in Europe in 2010.

Surface freight volumes from international trade can be further divided between domestic and international. The domestic component of international freight consists of that part of freight trips which take place within the borders of the origin or destination country, for instance between the ports and the production/consumption centers. We estimate that the domestic transport related to international freight represents around 10% of the total trade-related freight globally. This figure varies greatly depending on the geographic location of the main producers/consumers in each country. In China, where most of the economic activity is concentrated in coastal areas, the domestic link represents 9% of the total international trade related freight volumes. On the contrary, India's production and consumption centres are located inland and the share is 14%.

The domestic component of international freight represents a large share of total surface freight volume (national and international) in some countries. In China, we estimate this to grow from 9% in 2010 to 11% by 2050. In the United States, this share is estimated to be 15% in 2010. It could grow up to 40% by 2050 depending on future trade patterns, and especially on the growth of agricultural exports from the United States to China.

Figure 8. **Surface freight spatial density in 2010, 2030 and 2050**

Infrastructure capacity for international trade

Congestion at ports

Projected trade and freight flows at the 2050 horizon highlight the need to assess the capacity of existing national infrastructure such as port terminals, airports or road and rail infrastructure to deal with the bottlenecks that may emerge. Existing national infrastructure already faces issues of insufficient capacity, especially on surface links, in some regions of the world while some other regions are experiencing overcapacity, especially during the current period of continued slow economic growth.

Our results suggest that the container traffic related to international trade will double by 2030 (+73%) while by 2050 the additional traffic is nearly 300% of that today. These translate to over 1 billion TEU by 2030 and to nearly 2.2 billion TEU by 2050. Looking at the traffic by 2030, the greatest increases in absolute terms are for Southeast Asia (143 million TEU), China (94 million TEU), North Asia (54 million TEU), Western Europe (52 million TEU), and South Asia (37 million TEU) by 2030. In relative terms, the largest capacity increases would be needed in South Asia (193%), Southeast Asia (163%), North Africa (138%) and West Africa (137%).

Table 7. **Container traffic by sea area 2030 and 2050 and planned capacity 2030**

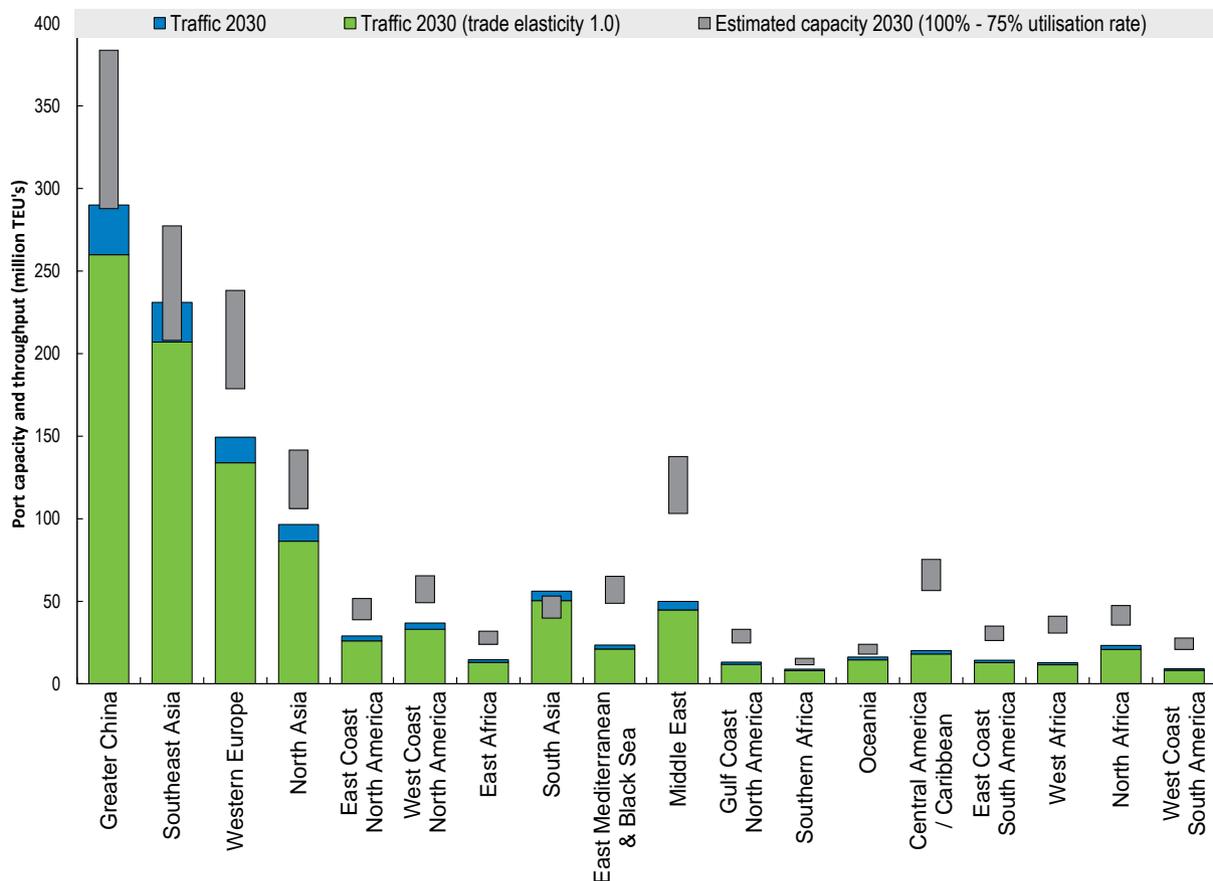
| Sea Area | Traffic 2013 MTEU | Traffic 2030 MTEU | Traffic 2050 MTEU | Estimated capacity 2013 MTEU | Planned capacity 2030 MTEU | Traffic – capacity 2030 MTEU |
|--------------------------------|----------------------|----------------------|----------------------|---------------------------------|-------------------------------|---------------------------------|
| Greater China | 196.4 | 290.0 | 432.2 | 248.3 | 383.8 | -93.8 |
| Southeast Asia | 88.0 | 231.0 | 426.6 | 124.4 | 277.3 | -46.3 |
| Western Europe | 97.8 | 149.4 | 231.3 | 168.1 | 238.2 | -88.8 |
| North Asia | 43.0 | 96.5 | 131.2 | 70.9 | 141.6 | -45.1 |
| East Coast North America | 23.9 | 29.1 | 75.0 | 42.4 | 51.7 | -22.6 |
| West Coast North America | 24.9 | 36.8 | 44.0 | 43.2 | 65.5 | -28.7 |
| East Africa | 8.2 | 14.6 | 28.4 | 13.0 | 31.9 | -17.3 |
| South Asia | 19.2 | 56.2 | 160.6 | 29.1 | 53.1 | 3.1 |
| East Mediterranean & Black Sea | 16.8 | 23.6 | 58.2 | 27.5 | 65.1 | -41.5 |
| Middle East | 36.7 | 50.0 | 55.3 | 50.9 | 137.6 | -87.6 |
| Gulf Coast North America | 7.4 | 13.2 | 19.1 | 11.8 | 33.1 | -19.9 |
| Southern Africa | 4.7 | 8.9 | 20.1 | 7.8 | 15.5 | -6.6 |
| Oceania | 11.2 | 16.2 | 36.4 | 17.1 | 23.9 | -7.7 |
| Central America / Caribbean | 19.6 | 20.2 | 33.4 | 29.5 | 75.4 | -55.2 |
| East Coast South America | 13.2 | 14.3 | 22.6 | 19.0 | 35.0 | -20.7 |
| West Africa | 5.4 | 12.8 | 31.7 | 8.8 | 40.9 | -28.1 |
| North Africa | 9.8 | 23.3 | 40.3 | 13.2 | 47.4 | -24.1 |
| West Coast South America | 7.9 | 9.2 | 25.3 | 14.0 | 27.8 | -18.6 |
| TOTAL | 634.3 | 1095.2 | 1871.9 | 938.7 | 1744.9 | -649.5 |

Based on the estimated capacity developments up to 2030 it seems that there would already be sufficient capacity planned in most of the regions to accommodate the future traffic growth. Several regions seem to have quite severe overplanning of capacity increases. Our projections for future freight are above the estimated capacity expansions only for South Asia (see Table 7).

These projections are subject to several uncertainties regarding future economic growth and trade elasticities, among others. To assess the potential impact of these uncertainties, we carry out sensitivity analysis with regards to two elements. First, we look at trade and freight projections based on the assumption that the elasticity of trade (in weight) to GDP will decline from 1.2 to 1.0 by 2030 and remaining at this level up to 2050. In our baseline scenario this elasticity declines from 1.4 in 2010 to 1.2 in 2030. And second, we investigate the effect of lower utilisation rates of ports, at 75% (instead of 100%).

Our sensitivity analysis shows that a decline of trade elasticity from 1.2 to 1.0 would lead to 10% lower container traffic levels by 2030 compared with the baseline. Figure 9 details these results by world region. When accounting for a lower utilisation rate, there is still overcapacity in 2030 for most regions. But for several other regions, the capacity difference between future traffic and capacity is less significant: especially in South Asia and Southeast Asia, current improvement plans may not be sufficient to cover the future growth in trade-related container movements.

Figure 9. **Expansion plans compared with traffic projections by sea area (MTEU)**



The above results assume that transshipment patterns remain constant over time. This may be true for several regions which do not naturally lend themselves to transshipment due to their geographical locations, for instance Scandinavia. However, in some regions, capacity constraints in some ports or increased competition may alter the transshipment patterns. Table 8 illustrates how relaxing transshipment assumptions affects capacity needs in the broader Mediterranean region. With current transshipment patterns, North Africa needs 138% more capacity by 2030. With relaxed transshipment assumptions, competition for transshipment services in the Mediterranean alters traffic patterns so that the capacity need for North African ports become smaller.

Finally, it is possible to look at capacity constraints in terms of the additional travel time and distance due to congestion on the quickest route. This is done by comparing the travel time and distance resulting from the equilibrium assignment of the constrained model with those of the shortest path assignment of the unconstrained model. If no additional capacity is created, trade distances increase by 43% by 2030 and 65% by 2050 as goods need to travel alternative routes. Also, the increase in freight delays would be 48% higher by 2030 and 84% by 2050. This is likely to have a significant negative impact on future GDP and trade growth. This effect is not included in the modelling for this project and would need to be investigated further, by looking at the impact of freight travel time on trade.

Table 8. **Container port capacity requirements by sea area 2030 (Mediterranean area)**

| Sea Area | Capacity 2013 MTEU | Capacity needs 2030 Current transshipment | Capacity needs 2030 Competition on transshipments |
|-------------------------------|--------------------|---|---|
| West Mediterranean | 43.8 | 7% | 46% |
| East Mediterranean & BlackSea | 27.5 | 40% | 102% |
| North Africa | 13.2 | 138% | 71% |

Congestion in hinterland connections

For hinterland connections (surface freight), capacity requirements are first measured against all capacity in place by region (measured in lane-km and track-km for road and rail respectively), even if the capacity is not located along the main freight corridors (see Figure 8). There is congestion near the ports and connection to centroids, where all cargo has to be handled and distributed. Yet, this congestion can occur on small distances, which does not significantly impact the overall performance of the freight network because degradation of performance at small utilisation rates is small.

The largest estimated capacity needs are for Asia, followed by Africa and Europe. These values expand significantly in 2050 especially in Asia and Africa, where surface freight infrastructure can become an impediment to trade activity.

Table 9. **Capacity needs for surface freight by continent**

| | Freight (billion tonne-kilometres) | | | Required capacity increase compared to 2010 (%) | |
|---------------|------------------------------------|--------|--------|---|------|
| | 2010 | 2030 | 2050 | 2030 | 2050 |
| Europe | 4 318 | 8 345 | 13 123 | 11 | 23 |
| North America | 2 763 | 5 097 | 9 320 | 6 | 15 |
| Asia | 8 956 | 26 202 | 58 092 | 35 | 67 |
| Oceania | 118 | 226 | 441 | 1 | 3 |
| South America | 619 | 1 044 | 1 913 | 3 | 9 |
| Africa | 630 | 2 024 | 7 853 | 12 | 46 |

Because there is a lot of underused capacity in areas with low levels of freight movements, we also compare surface freight traffic to freight activity but only account for areas less than 50 km away from ports or centroids, effectively limiting the analysis to places where congestion is most likely to occur. The results are presented in Table 10. Capacity needs now appear more clearly in Asia and Africa. In 2050, infrastructure in Asia and Africa will almost need to triple to go back to the performance levels of 2010. Overall capacity requirements are not very high but spatially focused where traffic congestion near ports need to be dealt with.

Table 10. **Capacity needs for surface freight by continent within 50 km of centroids and ports**

| | Freight (billion tonne-kilometres) | | | Required capacity increase compared to 2010 (%) | |
|---------------|------------------------------------|-------|--------|---|------|
| | 2010 | 2030 | 2050 | 2030 | 2050 |
| Europe | 1 458 | 2 616 | 4 009 | 23 | 44 |
| North America | 472 | 867 | 1 630 | 10 | 22 |
| Asia | 1 761 | 4 858 | 10 769 | 68 | 186 |
| Oceania | 32 | 64 | 113 | 2 | 12 |
| South America | 166 | 276 | 500 | 15 | 41 |
| Africa | 112 | 326 | 1 104 | 40 | 165 |

Our approach for measuring future surface freight capacity needs has some limitations. Typically, road and rail freight networks are shared capacity between freight and passenger transport (only some cases dedicated freight lanes exists). We do not take into account growth in passenger transport over the same time period. Our projections only include international trade related freight, hence excluding movement of goods between domestic destinations. Including both would naturally lead to higher capacity requirements. Finally, we do not make assumptions on modal shifts. All these are subject to future studies using more detailed data.

Future projections: Understanding uncertainties

The projections presented above should be interpreted with caution. Indeed, there is much uncertainty regarding the demand, especially for container port capacity. In addition to the uncertainty related to long term economic and trade projections, there exists possible developments in terms of shipping business models, containerisation rate, ship size and shipping routes.

Shipping business models

The current business model of container shipping is predominantly based on cost competitiveness; many of the other characteristics of shipping service, such as speed and reliability, are derived from the perceived need to control and cut costs. The ITF freight model does not take costs into account but translates cost increases in travel time increases. In practice, most of the goods transported by ship are fairly time insensitive: as long as travel times are known in advance and planned for, reduction of ship speed does not bother most freight forwarders – the customers of shipping companies. Slow steaming – reducing vessel speeds for example from 20 knots to 16 knots – has become common practice in container shipping since 2009, in essence to save costs as fuel consumption increases substantially with the increase of vessel speed. Despite significant decreases of fuel prices, speeds have remained at a structurally slower speed than before 2009.

There are various ways in which costs for shipping could increase in the future. ITF/OECD (2016) assesses the cost impacts of the introduction of new global sulphur emissions regulations by 2020 for container shipping. It projects that costs could increase up to 85%. The introduction of market-based mechanisms to reduce GHG emissions could also increase the costs of container shipping. Considering the wide application of slow steaming, slower speeds will provide less maneuvering room to mitigate cost. Little is known about the elasticity between containerised trade and the costs of container shipping. It is not unlikely that there is a point where cost increases will slow down containerised trade growth. This effect is not incorporated in the ITF model.

The increasing concentration of container shipping might also have an impact on routing patterns and port choice. Concentration has taken the form of consolidation of the sector via mergers and acquisitions, and of alliances of the large container lines. Via these alliances, container lines share vessel slots in order to increase utilisation rates of ships. There are four alliances (2M, G6, CKHYE and O3) that control around 95% of the main trade lanes. Ongoing and announced mergers in container shipping (Cosco and China Shipping, CMA*CGM and APL) will lead to a shake-up of the current alliances structure and might lead to three instead of four alliances. The emergence of these alliances has increased the risk for ports to abruptly lose a large share of containerised cargo. This makes container traffic projections for ports even more uncertain. The consolidation of cargo via alliances could also mean that container shipping will move towards more hub and spoke routing patterns, enforcing the risk of more variable traffic flows.

A characteristic of container shipping is fleet overcapacity. This is particularly large at the moment and will likely continue to be a relevant characteristic in the years to come. There is a relation between fleet overcapacity and terminal capacity. Fleet overcapacity has facilitated slow steaming and has to some extent transformed ships into moving warehouses; with less need for storage capacity at ports.

Containerisation rate

The spectacular growth of containerised trade over the last decades has been driven to a large extent by trade growth, but also to some extent by the process of containerisation. During this period more and more goods, previously transported as breakbulk or bulk, have been containerised. As a result, the container shipping sector has grown, partly at the cost of general cargo shipping and reefer shipping, replaced by reefer containers. If this process of containerisation has reached saturation, at least in the developed market economies, demand could be lower than projected in previous chapters.

Effects of larger ship sizes

Over the last two decades, container shipping has seen a quadrupling of ship size, with regards to average and maximum size (ITF/OECD, 2015). Large ships need different infrastructure and superstructure than small ships. The main differences consist of the draft of access channels and berths, quay length and

strength, yard size, crane height and width. As container terminals are usually planned and designed for several decades, and as container ship upsizing has taken place at a very fast pace, container terminals are often not equipped for large ships. The terminal capacity, expressed in million TEU introduced in the analysis of the previous chapters, obscures the issue. The existing capacity may be ill-suited for the ships calling that port range.

It is difficult to predict what the size of container ships will be in 2030 and 2050. The development of ever larger ships has been driven by the search for economies of scale by ship owners. These economies of scale are diminishing as the size of container ships increases, but there will still be some economies of scale to be reaped from even larger ships. The cost savings of larger ships are offset by the costs to the whole transport chain; these costs are however not internalised by ship owners (ITF/OECD, 2015). The crucial question is whether some of the system costs will become internalised and offset the economies of scale also for the shipowner. This could for example happen if the necessary port and terminal investments translate into higher port and terminal charges for big ships; if dredging costs need to be covered by shipping lines; or if insurance premiums for the largest ships substantially rise due to the higher system risks that they represent.

Alternative shipping routes

The projections in this project assume that current shipping routes will continue to be used. Various projects in discussion may change these routes. The Kra Canal could provide a supplement to the flows currently going through the Malacca Straits; the Nicaragua Canal could provide an alternative to the Panama Canal and would be better able to accommodate the biggest container ships. Various proposed land bridges in Latin America could also provide new options to connect the Atlantic and Pacific Oceans. The Northern Sea route might also be able to accommodate more shipping, even if the prospects for regular liner services seem limited.

Long-range rail corridors might also at some point become an alternative for certain maritime trade routes. This is currently not the case, considering that ocean shipping is so much cheaper and that most of the goods are fairly time insensitive. Long-distance freight rail has so far been more in competition with air cargo but the equation could change considering some of the increased costs that maritime transport could have to face, such as the low sulphur regulations.

In addition, both China and the EU have strategic visions that could change the port hierarchies of different continents. Two important initiatives to build up alternative port capacities include the Trans-European transport network (TEN-T) **of the EU and China's One Road One Belt (OROB) network. The consequences** for Europe could be a counter-weight to the dominance of North European ports. Also in other continents, this could mean the establishment of a parallel (or partly parallel) network. For example, in the OROB, the role of Singapore as a Southeast Asian hub seems to be supplemented by Malaysia and Indonesia.

In short, any study of capacity constraints cannot forego the analysis of the potential sources of uncertainties, some of which are listed above. For all those responsible for long-term port planning, private and public sector alike, knowledge and intelligence to clarify the trends sketched above as they are unfolding is essential.

5. Policy implications

This chapter outlines the policy implications of the projections of the previous chapters. It indicates the main challenges policies would have to resolve. These challenges include mechanisms to plan for uncertainty, planning holistically considering that the weakest link determines the performance of the overall freight transport system; and optimising capacity. This chapter will also discuss the financing models for capacity expansions.

Port capacity: Planning for uncertainty

Planning for port capacity is always a difficult balancing act. One wants to avoid both over-capacity and under-capacity, but port infrastructure is per definition lumpy. In practice this means that container ports almost never reach the optimal level of capacity, which we estimated to be at around 75%. Container terminals are lumpy pieces of infrastructure and investment: most new capacity is suddenly available, but the utilisation of that new capacity will take place gradually. In case of new ports, it can take several years before carriers are convinced of the value of including the new port in their loops. So an assessment of utilisation rates of container ports only makes sense if seen in this dynamic perspective.

This means that timing is crucial, but often challenging. Planning for new port capacity often begins in boom times, but realised capacity might come on the market when there is a slump. This is for example the case in Northwest Europe where a lot of the new container terminal capacity (Rotterdam Maasvlakte 2, London Gateway, Jade Weser Port) came on the market in the recent years of economic downturn. It also underlines the importance of quick planning procedures and long term strategic planning.

Expanding port capacity usually takes a considerable amount of time. Dredging might take several years, extension and strengthening of quay walls one to two years, port hinterland connections easily more than five years, and new port terminals at least five but frequently more than ten years if land needs to be reclaimed (ITF/OECD, 2015). For most of these adaptations, the actual time for construction or doing the works is relatively short, but it is the decision-making process that often takes the greatest amount of time. Most of these projects are sensitive, considering that they involve many stakeholders with different interests and often diverging conceptions of a desirable outcome.

Inevitably, a lot of time is invested in consultation and – where possible – creating consensus on a concrete proposal, followed by various impact assessments (feasibility, cost-benefit analyses, economic, environmental and social impacts), planning permits, bidding processes for procurement or public-private partnerships (ITF/OECD, 2015). Frequently, stakeholders that oppose a proposal will use every legal possibility to block smooth decision-making on the proposal. In practice, it can take decades before projects see the light; in many cases projects never materialise. Several countries have made efforts to substantially reduce lead times for infrastructure investments, e.g. by bundling different permits needed for infrastructure projects and streamlining procedures for infrastructure project timelines.

Phasing in of terminal capacity is often used as a way to smoothen lumpiness. This means that the groundwork is finished being laid, but equipment and refurbishing can come in phases. Consequently, the terminal area is prepared, the land reclamation done (if necessary), the quays constructed and access channels and berths dredged; however the refurbishing of the terminal and the equipment would only be done for the part of the terminal that would be used first. As decisions have been made, approvals been granted, the phasing in of expansions of terminals could be done in such a way that terminal capacity is fairly neatly aligned with demand for container transport in that region. For example, the DCT-terminal in Gdansk started in 2007 with a capacity of 0.5 million TEU, but was planned for a much larger capacity, to be reached in different stages and in line with demand growth.

Forward-looking planning is essential. This includes the anticipation of possible future demand, a strategy for where this demand could be accommodated and which areas would be needed to be reserved for future port development that would be needed in this respect. For example, land reservations by Singapore for a new container port further away from the city (Tuas), with 50 million TEU additional capacity, were planned decades in advance.

Such long-term engagements can also be expressed in strategic visions that are to a greater or lesser extent publicly available. These visions, which can take a time horizon of several decades, can identify new directions of development, prioritise investments and identify future bottlenecks. Ports such as Rotterdam, Vancouver and Melbourne all have long-term strategic plans (OECD, 2014). If well designed, the strategic planning process can help to engage main stakeholders, strengthen links with clients and create local goodwill. Long-term planning is most effective when these long-term visions somehow act as a catalyst for innovation and new perspectives. In order to achieve this, the planning horizon of these strategies would need to have far away targets that should be flexible and embedded in different scenarios. The vision would somehow need to be imaginative rather than technocratic. For realisation to occur, these visions would need to be translated into operational plans and regularly updated and revised (OECD, 2014).

Good port planning can have an important impact on port performance, by optimising existing port capacity. Port master plans describe the main functions of the port, their location and inter-relationships; these plans should indicate where new traffic will be allocated and which actions are required to achieve this. Such a master plan forms the basis of detailed planning on various different levels, such as berth allocation planning, yard planning, traffic planning within the port area, planning of intermodal operations, lock operation planning and planning related to tidal conditions in estuary ports (OECD, 2014). All these elements should be aligned in order to realise smooth port operations. The gains of sound port planning can be considerable; e.g. the differences between good and bad yard planning in similar conditions can have an impact on handling time of about 30% (Roy & De Koster, 2013).

As weak as your weakest link: The need for holistic planning

At the port level, bottlenecks can exist with respect to maritime access, sea-to-shore, yard and port gate. Theoretical design capacity can in practice be constrained by any of these bottlenecks. This means that the desire for efficiency would need to be part of the behaviour and procedures of all the stakeholders in ports, along the whole chain, making use of best international practices, e.g. truck appointment systems with regards to port gate operations. In addition, smooth operations are facilitated by smooth information exchange between the different port actors, e.g. via a port community system (PCS).

A great high capacity port cannot be used to full potential if the connecting road or rail network is not equipped to handle similar cargo volumes. Strong hinterland connections require certain provisions within the port. This includes direct rail access to the quays, smooth interconnections with the railway network outside the port and canals linking berths with inland waterways. These provisions are far from universally applied. In many ports, several moves would be required before a container (or other cargo) arrives on a train wagon or barge; the more moves are needed, the less competitive these modes of transportation get in comparison to truck transport (OECD, 2014).

In other ports, there is no direct link with inland waterways, which means that barges would have to get to the port terminal by sea, which is not allowed for many barges and would require special vessels or changes in ship design. These examples are in many cases related to fallacies in port design and lack of holistic transport planning. The ports that have realised sustainable modal splits have extensive railway tracks on port terminals and might have dedicated river terminals and short sea terminals, result of joined-up transport planning across transport modes (OECD, 2014).

In addition to these measures, regional approaches towards freight transport, e.g. distribution centres and extended gates, might be needed to create enough critical mass for non-truck transportation. Trucks generally have a competitive advantage for shorter distance transport; only when distances get longer does freight transport by train generally become a competitive transport mode. Large economies of scale can be reaped, but it requires a logistical organisation in the form of distribution centres. Here, large amounts of containers and cargo can be grouped before being dispatched to individual destinations (OECD, 2014). Such a system of selective dry ports or distribution centres has made it possible for relatively small container ports such as Gothenburg to achieve high railway shares in total hinterland traffic (ITF/OECD, forthcoming).

A related approach is that of extended gates, which basically re-located part of the port closer to the hinterland, by displacing cargo handling, customs and other procedures towards an inland port. This relocation allows for a decongestion of the port. Such a concept is well developed by the Port of Antwerp that has engaged in a large set of partnerships creating a network of inland extended gates (ITF/OECD, forthcoming). Ports have generally become more aware of the need to be better linked to hinterlands, with various ports taking stakes in inland terminals and distribution centres, creating dry ports, merging with inland ports and facilitating part of the hinterland transportation (OECD, 2014).

Doing more with less: Optimising capacity

There is still a lot of low hanging fruits to make best use of existing port capacity. Although many ports declare to be open non-stop, **practice is much different. The majority of ports have the lion's share of their activity taking place during day time.** This is the case because one or more actors in the port supply chain do not work at night or on weekends. In many ports, customs and inspection agencies only work during the daytime. Often this is the case because there is no demand for opening up during the night. Trucks hardly ever come to ports at night, in many cases because they would not be able to bring cargo to or get cargo from warehouses or shippers, which are in many cases not open at night. Activity during the night time and weekends would increase the utilisation rates of ports, arguably by one-third (the night time hours).

More co-ordination between carriers and terminals on stowage planning could bring down ship turnaround times and as such increase terminal capacity. Stowage planning determines where containers are placed in a ship. Stowage planning is very important because it has consequences for the number of cranes that could be used simultaneously; if all the containers destined for one port would be stowed in one particular area of the ship, this means that these containers could only be handled by a few cranes, not the full amount, so the ship handling rate will be low in this case.

If the cargo is well balanced over the ship, the port terminal can be much more effective. This requires close co-operation between carriers and terminals: the terminal needs to be organised for outbound cargo in the yard, in such a way that it is in line with the stowage planning of the ship. This can be more easily arranged in terminals that are dedicated for a particular shipping line. There is ample evidence to suggest that co-operation between carriers and terminals is at the core of terminal productivity (e.g. JOC, 2015).

Densification of port operations is also a fairly cheap way to create more capacity. This could be achieved by putting higher stacks of containers in the container yard; stacking four-five containers high instead of only two-three containers. This might require changing yard equipment; high stacking requires rubber tyred gantry cranes (RTGs) or rail-mounted gantry cranes (RMGs) instead of reachstackers. The capital costs for this equipment are higher than with reachstackers, but fairly marginal in comparison with port expansion projects. More sophisticated yard planning would also be needed in that case, as lack of planning would lead to more unproductive moves. Equipment upgrades, such as container cranes with the possibility of twin lifting and tandem lifting, could also speed up ship-to-shore operations and as such increase capacity without building new terminals.

Certain developments will go in the opposite direction: the increase in ship size brings larger peaks of cargo, which require larger yards for the same amount of cargo. Mega-ships generally generate a higher peak load in terminals for which the container yard generally operates as a buffer. This has affected the optimum relationship between quay length and yard area. Nowadays, more yard space is needed per given quay length than was the case in the past: this could be considered one of the additional external costs generated by mega-ships (ITF/OECD, 2015).

Approaching funding: Who pays for what?

In many countries, private terminal operators carry out investments that increase port capacity. So port capacity planning by governments and public port authorities, in many cases, is in fact the planning and design of port terminal concession procedures and contracts.

The last decades have seen a sharp increase in the number of port concessions, as a way to get the private sector involved. This is illustrated by the increase in the share of global container volumes handled by private terminal operators, from around two thirds in 1996 to four-fifths in 2014 (Drewry, 2015). This has resulted in a large inflow of private investments into the ports sector. These private investments are often in the superstructure of ports, such as cranes, yard equipment and warehouses. In some cases, private actors also invest in infrastructure and sometimes even public goods, such as sea defense walls. For brownfield projects, the main concessionaires are private terminal operators sometimes in combination with financial institutions. For greenfield projects, construction and dredging companies are sometimes also involved in terminal concessions.

Income from concessions is now one of the main sources of revenue of port authorities. Although there are substantial differences between ports with respect to their revenue sources, income from concessions might generate around one-third of operational revenues of main EU ports. The other large revenue source is the port dues, which are related to the right to use the port and its services. The concession payments that operators would be willing to pay depend on various factors including location, quality and quantity of port services, hinterland connectivity and other factors. One of the other elements is the shadow price of land of the port terminal.

This emergence of port concessions is driven by the need for higher productivity. Cargo handling activities can be considered commercial activities and most countries consider that there is no specific reason why this should be done by the public sector; one could rather assume that a public sector mindset and approach would not facilitate the efficiency and productivity that the private sector can achieve. The largest private terminal operators have now developed into global terminal operators, which can have the additional advantage of acting as transmission mechanisms of best practices from other terminals within the same company. There is research that indicates that global terminal operators have a positive impact on the efficiency of container terminals, although this does not apply for terminal operators driven by global container carriers (Cheon, 2009).

In case of sufficient volumes, new concessions could be used to increase intra-port competition. The idea is that new maritime trade growth provides ports with need for more capacity that could be provided by new actors, which would introduce more competitive pressures on the incumbent operator, which might improve services levels and possibly decrease handling rates. Thus, it has become common practice to use port expansions as the occasion to increase intra-port competition and introduce more cargo handling services.

However, there are various examples where this has not happened, even if promotion of competition was an explicit goal of the concession. In the case of Casablanca, the subsequent concessions for new container terminals have strengthened the position of the former public operator turned private (Marsa Maroc). This left the second terminal with relatively unfavourable characteristics to CMA*CGM, and the newest terminal

also to Marsa Maroc. This situation was described by some observers as a missed opportunity to introduce real competition (El Khayat, 2014).

In Abidjan, the existing container terminal was operated by a joint venture of Bolloré and APM Terminals, reflecting a wider situation of port terminal duopoly of these operators in West Africa. The bidding document for the new container terminal 2 (CT2) explicitly mentioned the need for more competition as a motivation for the new concession. Yet, the concession was won by a consortium, which included Bolloré and APM Terminals (Merk et al. forthcoming).

Too much competition in a sluggish market could lead to terminal overcapacity. This can be illustrated by low terminal capacity utilisation rates. The situation in Europe is fairly eccentric in this respect: whereas the average utilisation rate of container terminals in 2014 globally was 67.6%, this rate is considerably lower in all parts of Europe: 50.5% in Scandinavia & Baltic, 56.4% in Northwest Europe, 61.3% in East Mediterranean & Black Sea, and 62.7% in West Mediterranean (Drewry, 2015). This means that the cargo volumes fall well short of the combined minimum efficient scale of the container terminals. The result is a large overcapacity of container terminals: there is competition but not enough cargo. As a result, certain terminals could be obliged to close or temporarily suspend operations; in North West Europe this for example the case of the Zeebrugge International Port container terminal of PSA.

A way to find the right balance between terminal under-capacity and over-capacity could be strategic planning of port development and investment at the appropriate territorial level. Various countries, such as Canada, France and India, have established a national port hierarchy. They define a port system in which **some ports are of “national importance” whereas** other ports merely represent regional or local importance. National involvement in ports often takes the form of investment in port infrastructure or port-related infrastructure, such as hinterland corridors and dredging. Although port policies at the national level could help to define priorities for public spending in ports and port-related infrastructure, one could wonder if such co-ordination should not also take place at the level where port competition takes place. In North Europe, this could for example be at the level of the Hamburg-Le Havre range. However, co-ordination at this intervention level rarely takes place: although the directors of the main ports in the area meet regularly, they do not discuss coordination of commercial or strategic development. Co-ordination of transport ministries in these countries does not seem to include port strategic planning. There are some examples of supra-national planning of infrastructure, such as the Trans-European transport network (TEN-T), **and China’s** One Road One Belt (OROB) strategy, that could be tools for finding a balance in port capacity development.

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Annex : Network characteristics

Table A1. **Statistical characterisation of global freight network**

| Link or node typology | Number links or nodes | Length (km) |
|---|-----------------------|-------------|
| Connector between airports and ports (islands with sparse road network) | 448 | 1 416 |
| Connector between airports and roads | 4 730 | 60 055 |
| Connector between airports or ports to centroids (islands with sparse road network) | 135 | 406 |
| Connector between centroids and roads | 850 | 5 240 |
| Connector between ports and maritime routes | 2 810 | 227 409 |
| Connector between ports and roads | 2 529 | 30 631 |
| Connector between rail and roads (at rail stations) | 4 475 | 12 664 |
| Connector between river and roads (near cities) | 2 509 | 52 949 |
| Connector between rivers and maritime routes | 144 | 19 265 |
| Inland waterways routes | 1 790 | 176 179 |
| International airports | 1 969 | - |
| International flights routes | 34 102 | 60 981 952 |
| International ports | 2 609 | - |
| Maritime routes | 8 290 | 4 059 789 |
| Rail network | 25,417 | 927 157 |
| Regular ferry services routes | 411 | 62 279 |
| Road network | 156 894 | 4 862 585 |

Table A2. **Speed used in the network model by different world regions**

| Infrastructure type | Speed km/h | | |
|-----------------------------|------------------|-------------------------------------|-------------------|
| | Europe and Japan | Australia, Canada and United States | Rest of the world |
| Road ^a | | | |
| Major highways | 80 | 80 | 70 |
| Secondary highways | 65 | 65 | 55 |
| Beltways and national roads | 40 | 40 | 30 |
| Tracks or unpaved roads | 10 | 10 | 5 |
| Rail ^b | | | |
| Electrified | 40 | 35 | 25 |
| Non electrified | 30 | 30 | 15 |
| Sea ^c | | | |
| Bulk vessels | | | 22.2 |
| Container vessels | | | 41 (22 knots) |
| Air ^d | | | 600 |
| Inland waterways | | | 15 |
| Connectors ^e | | | |
| Road connector | | | 30 |
| Sea connectors to ports | | | 15 |
| River connector to sea | | | 15 |

Source: a) authors' estimates based on speed limits and road infrastructure quality; b) UIC, International Railway Statistics 2010; c) UNCTAD, Review of Maritime Transport 2010 ; d) authors' estimates based average travel times for commercial flights Europe to other continents obtained from www.travelmath.com retrieved in April 2014; e) authors' estimate for the setting of road and sea connectors.

Table A3. Dwelling time used in the network model by different world regions

| Intermodal connection | Dwelling times (hours) | | |
|-----------------------|------------------------|-------------------------------------|-------------------|
| | Europe and Japan | Australia, Canada and United States | Rest of the world |
| Air/Air | 4 | 4 | 72 |
| Air/Road - Road/Air | 4 | 4 | 72 |
| Air/Rail - Rail/Air | 4 | 4 | 72 |
| Air/Sea - Sea/Air | 22 | 22 | 72 |
| Rail/Sea - Sea/Rail | 49 | 49 | 96 |
| Rail/Road - Road/Rail | 31.5 | 31.5 | 31.5 |
| Road/Sea - Sea/Road | 49 | 49 | 96 |

Source: Fluidity Indicator Project (Canada's Gateways), Transport Canada 2012

The total network characteristics by world region are provided in Martinez et al. (2015).

Table A4. Sea areas container ports expansion plans

| Sea Area | Capacity expansion Drewry (annual rate %) | Capacity expansion Ocean Shipping Consultants (annual rate %) | Maximum capacity expansion (annual rate %) |
|--------------------------------|---|--|--|
| Central America / Caribbean | 4.80 | - | 4.80 |
| East Africa | 4.60 | - | 4.60 |
| East Coast North America | 1.00 | - | 1.00 |
| East Coast South America | 3.10 | - | 3.10 |
| East Mediterranean & Black Sea | 4.40 | - | 4.40 |
| Greater China | 2.20 | - | 2.20 |
| Gulf Coast North America | 5.30 | - | 5.30 |
| Middle East | 5.10 | 4.31 | 5.10 |
| North Africa | 6.60 | - | 6.60 |
| North Asia | 1.60 | 3.52 | 3.52 |
| North West Europe | 1.30 | - | 1.30 |
| Oceania | 1.70 | - | 1.70 |
| Scandinavia & Baltic | 4.10 | - | 4.10 |
| South Asia | 8.00 | 3.07 | 8.00 |
| South East Asia | 3.90 | 4.09 | 4.09 |
| Southern Africa | 3.50 | - | 3.50 |
| West Africa | 8.00 | - | 8.00 |
| West Coast North America | 2.10 | - | 2.10 |
| West Coast South America | 3.50 | - | 3.50 |
| West Mediterranean | 1.50 | - | 1.50 |

Table A5. **Characterisation of port capacity by world sea area**

| Sea Area | Medium and large ports * | Container capacity modelled (million TEU) | % of modelled container capacity | Dry bulk capacity (million tonnes) | Liquid bulk capacity (million tonnes) | Break bulk capacity (million tonnes) | Vehicle Ro/Ro (million tonnes) |
|--------------------------------|--------------------------|---|----------------------------------|------------------------------------|---------------------------------------|--------------------------------------|--------------------------------|
| Central America / Caribbean | 34 | 18.96 | 72.8% | 50.10 | 17.70 | 45.38 | 9.03 |
| East Africa | 10 | 7.06 | 68.1% | 19.39 | 6.57 | 16.80 | 3.68 |
| East Coast North America | 34 | 34.43 | 86.4% | 329.52 | 372.22 | 181.81 | 65.99 |
| East Coast South America | 31 | 10.00 | 64.1% | 703.93 | 259.95 | 104.77 | 21.14 |
| East Mediterranean & Black Sea | 40 | 14.35 | 75.1% | 286.96 | 205.77 | 150.13 | 37.85 |
| Greater China | 34 | 187.49 | 96.3% | 1224.77 | 490.30 | 1100.56 | 163.73 |
| Gulf Coast North America | 16 | 8.51 | 95.3% | 402.42 | 590.76 | 1345.17 | 16.50 |
| Middle East | 28 | 36.62 | 87.9% | 221.47 | 49.79 | 166.89 | 25.71 |
| North America lakes | 12 | 0.86 | 100% | 117.32 | 29.37 | 105.70 | 15.74 |
| North Africa | 16 | 11.61 | 87.2% | 73.38 | 22.44 | 67.08 | 13.65 |
| North Asia | 27 | 42.71 | 69.6% | 853.07 | 442.63 | 780.62 | 178.27 |
| North West Europe | 55 | 54.99 | 59.1% | 534.01 | 841.14 | 149.65 | 102.00 |
| Oceania | 25 | 15.55 | 100% | 640.09 | 162.61 | 576.06 | 86.76 |
| Scandinavia & Baltic | 50 | 7.90 | 52.8% | 197.17 | 189.50 | 89.86 | 74.79 |
| South Asia | 17 | 18.02 | 68.7% | 232.90 | 58.97 | 209.16 | 31.33 |
| South East Asia | 40 | 82.95 | 79.3% | 247.64 | 73.45 | 221.41 | 35.58 |
| Southern Africa | 7 | 5.41 | 84.1% | 102.02 | 26.14 | 92.00 | 13.94 |
| West Africa | 20 | 8.98 | 87.2% | 44.31 | 14.41 | 40.02 | 8.31 |
| West Coast North America | 33 | 28.16 | 70.54% | 133.87 | 162.72 | 128.86 | 30.64 |
| West Coast South America | 21 | 7.88 | 67.7% | 22.88 | 8.11 | 20.84 | 4.37 |

*Ports with capacity greater than 500 000 TEU per year.

Capacity to Grow

Transport Infrastructure Needs for Future Trade Growth

This report examines what increased global trade means for the world's transport infrastructure. Growing, more complex international freight flows will change capacity requirements and reshape the global transport networks over coming decades. Policy makers today must understand how these forces are likely to play out and what uncertainties exist with regard to these developments. Only then can they ensure adequate and timely investment into transport infrastructure that will continue to serve as the backbone of global trade and economic development.

The analysis builds on the award-winning International Freight Model of the International Transport Forum (ITF) that has been further refined to account for future capacity needs and improve the accuracy of projections looking towards the year 2050.

The work for this report was carried out in the context of a project initiated and funded by the International Transport Forum's Corporate Partnership Board (CPB). CPB projects are designed to enrich policy discussion with a business perspective. Led by the ITF, work is carried out in a collaborative fashion in working groups consisting of CPB member companies, external experts and ITF researchers.

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