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Transport 2040: Automation, Technology, Employment - The Future of Work

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WORLD MARITIME UNIVERSITY

TRANSPORT 2040

AUTOMATION TECHNOLOGY EMPLOYMENT

THE FUTURE OF WORK

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TRANSPORT 2040

AUTOMATION TECHNOLOGY EMPLOYMENT

THE FUTURE OF WORK

"Technological advances may disrupt labour markets as traditional jobs change or disappear, even as the number of young job-seekers continues to grow. Re-training will be needed at previously unimaginable scales. Education must adapt, from the earliest grades. And the very nature of work will change."

António Guterres, Secretary-General, United Nations
Address to the General Assembly, 25 September 2018

"Technological advancements today, including automation, are making transportation more complex and sophisticated. A key strategic direction for IMO is the integration of new and advancing technologies in the regulatory framework - balancing the benefits derived from new and advancing technologies against safety and security concerns, the impact on the environment and on international trade facilitation, the potential costs to the industry, and their impact on personnel, both on board and ashore. Member States and the industry need to anticipate the impact these changes may have and how they will be addressed. IMO's role is to ensure that relevant international standards are adopted to ensure a level playing field for shipping and enable the seamless introduction of any new technology which may have benefits for safety, security, facilitation of trade and environmental protection. It is also important to ensure that the necessary skills that will be required to handle the new technologies are integrated into relevant IMO instruments."

Kitack Lim, Secretary-General, International Maritime Organization

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"How can we manage transformative change at work, caused by multiple factors – technology, demographics, climate change, globalization – to ensure decent work, stability and social justice? It means anticipating technological changes and assuring that education and skills in the labour market keep pace but fundamentally it calls for a clear focus on the human objectives of policy development."

Guy Ryder, Director-General, International Labour Organization

"The challenges of automation, new technology and the future of work are some of the most important facing workers today. For trade unions, we must be strong enough to be able to shape change. Understanding potential impacts and opportunities for our members and preparing the appropriate responses are key. This includes enhancing our engagement with industry partners and identifying appropriate education, training and capacity-building needs of our members and workers in the transport chain. Transport workers of today and tomorrow must be equipped with the required knowledge, skills and expertise for the jobs of tomorrow. The ITF-WMU study provides the information needed to support these aims. The ITF remains committed to working in partnership to ensure our unions and members are central to developments in building the future of work."

Stephen Cotton, General Secretary, International Transport Workers' Federation

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FOREWORD

Transport is the foundation of global trade and growth in the economy. There are millions of transport workers that keep the world moving and make vital contributions to developments in the industry. Representing these workers, the ITF and our affiliates must always be looking to enhance our knowledge, skills and competences to deliver.

Transport workers have historically been at the forefront of change but today, we face a new challenge. Automation and new technologies are transforming the economy, politics, society, and trade unionism. We must strive to ensure the voices of transport workers are not only central to the debate, but shaping the future of work.

Automation and technological advances undoubtedly present challenges, but also opportunities. Jobs will intensify or shift to other parts of the economy. There are many things we, as a society, can do to stop the harmful effects of technology. We can secure regulations. Workers can use new technology to organise. Collective bargaining can ensure technology improves working conditions. By working together with all stakeholders, we can make sure new technologies make working and living life better.

The effects of automation and new technologies are not inevitable; they are a policy choice. Politicians, employers and workers have the power to make digital technology a tool for positive change. Collectively, we must grasp this opportunity to share the gains of new technology.

Thus, this report comes at a critical time and provides us with the assessment we need of how automation will affect the future of work in the transport industry. Its methods of analysis allow us to deepen our understanding of the issues at hand and the key findings will play a crucial role in framing the debate as we move forward.

The report tells us that: in many areas of global transport, the pace in the introduction of automation will be gradual; regional changes in transport patterns are expected; the pace of introduction and diffusion of technologies will be influenced by the local context.

It is clear that solutions for transport workers will be different across different sectors and regions.

However, we will only find those solutions, and solutions for wider industry, by working in close collaboration with industry partners. The ITF has a long and proud history of representing the interests of maritime workers in the International Maritime Organisation (IMO), and we remain committed to working at the national, regional and international levels to build a better future. We are extremely grateful to the World Maritime University (WMU) for producing this report and we look forward to reaping the benefits; we are proud to call them a partner.

Finally, an important aspect of the report is its contribution to delivering the United Nations Sustainable Development Goals (SDGs). The ITF will continue to play our part in ensuring we meet the common objectives, not just for the benefit of our members but for the future of our global society.

General Secretary
Stephen Cotton
International Transport
Workers' Federation

PREFACE

Transport provides a vital service to the national economy and the global community. Innovation and technology have always been part of its development and have enabled transport to become a driver for industrialization, globalization and development. New technologies and increasing levels of automation have often been introduced in transport for safety or efficiency reasons and most recently also for the benefit of the environment. However, every new invention changes the nature of work. It may require new skill sets or it may change working routines. It may lead to a reduced demand for workers of a certain profile and may create new demands for workers with different qualifications. This is not unprecedented and similar situations have been observed during the industrial development of our global community. What always has been an issue of concern in times of rapid technological developments is the impact of the changes in the nature of work on the society and on employment.

We are today in a phase called the 4th Industrial Revolution – a period that is characterized by the integration of artificial intelligence and higher degrees of automation and autonomy into the industry. The transport sector has always been impacted by technological developments over the years. What we are however experiencing today is an even greater rapid pace of technological developments. As a result, a number of questions in relation to the implications have been raised by many stakeholders in ongoing discussions at national and global levels. Those questions relate to the drivers of technological progress, timelines for the introduction of new technologies and the implications that these new technologies may have on the labour market in the short, medium and long-term.

This report is the outcome of a two-year project, undertaken by World Maritime University (WMU) and funded by the International Transport Workers' Federation (ITF), to investigate global trends in automation of the transport sector and to assess its implications on jobs and employment in the medium term and the future. This report summarizes the most significant findings of the project and is one of the first studies to discuss the implications of technologies and automation for the transport industry globally up to the year 2040. The report begins with a review of technological developments expected to be introduced in transport in the years to come. It continues with a forecast of transport volumes and streams in order to identify how the development of global trade may impact the further introduction of technologies and automation in transport globally. This is followed by an assessment of the segments of the global workforce in transport that could be affected by these developments and in which way. In order to understand the global perspective of these developments, a number of country profiles have been developed and a few case studies have been included at the end of the report.

WMU, which is established within the framework of the International Maritime Organization (IMO), has access to the specialized organizations of the United Nations (UN) and its bodies. The research team was therefore able to closely work with a number of UN institutions who work on issues relevant to this study. This has helped to address the complex nature of this project in a comprehensive way. I am very grateful for the support given by not only the UN institutions, but also by the many other contributors in international organizations, government institutions, industry and academia. Without their valuable support, this study would not have been able to produce the results presented in this report. My special thanks, however, go to the ITF who had the necessary confidence in WMU and allowed us to undertake the research and prepare this report. I am especially grateful that the ITF highlighted from the beginning until the end of the project that WMU enjoys full academic freedom in line with the WMU Charter to create an impartial report.

I believe that with this necessary prerequisite, this report can form an impartial basis for further discussions about automation, technologies and employment in the transport sector and the related policy considerations and actions required to respond to and address the implications for a sector – transport – that is vital to the national economies and to the global economy as a whole. It is our hope that this report will make a significant contribution as well to the Future of Work at a time when the International Labour Organization (ILO) is celebrating its 100th Anniversary in 2019 and the IMO Maritime Safety Committee at its 100th Session in December 2018 approved the framework and methodology for the regulatory scoping exercise on Maritime Autonomous Surface Ships (MASS). The IMO will also be analysing and determining the most appropriate way to address MASS operations, taking into account the human element, technology and operational factors.

We hope that this report will add value to on-going discussions and help prepare the transport industry to continue to contribute to the wellbeing of societies and communities worldwide and provide decent work for all. As an academic institution of the IMO, we stand ready to play our part in supporting research, education and capacity building in support of the UN Development Agenda 2030 and the related Goals.

President
Dr. Cleopatra Doumbia-Henry
World Maritime University

CONTENTS

ABBREVIATIONS AND ACRONYMS

4IR	Fourth Industrial Revolution
AGV	Automated Guided Vehicle
AI	Artificial Intelligence
AL	Autonomy Level
ANTS	Automated Nano Transport System
ASEAN	Association of Southeast Asian Nations
ATC	Air Traffic Control
ATM	Air Traffic Management
BLS	Bureau of Labor Statistics
ECMT	European Conference of Ministers of Transport
EU	European Union
Eurostat	European Statistical Office
GDP	Gross Domestic Product
GPS	Global Positioning System
HAShips	Highly Automated Ships
HGV	Heavy Goods Vehicles
IACS	International Association of Classification Societies
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
ICT	Information and Communications Technology
ILO	International Labour Organization
IMF	International Monetary Fund
IMO	International Maritime Organization
IoT	Internet-of-Things
IoV	Internet-of-Vehicles
IRF	International Road Federation
ISCO	International Standard Classification of Occupations
ITF	International Transport Workers' Federation
MaaS	Mobility-as-a-Service
MASS	Maritime Autonomous Surface Ships
NextGen	Next Generation Transport system (in the U.S.)
NGT	Next Generation Train
O*NET	Occupational Information Network
OCC	Operations Control Centres
OECD	Organization for Economic Cooperation and Development
PIAAC	Programme for the International Assessment of Adult Competencies
RFID	Radio-Frequency Identification
SAE	Society of Automative Engineers (in the context of Automation Level scale)
SCC	Shore Control Centre
SESAR	Single European Sky ATM Research
TOS	Terminal Operation System
TRL	Technology Readiness Level
UAS	Unmanned Aircraft System
UN	United Nations
UNCTAD	United Nations Conference of Trade and Development
UNECE	United Nations Economic Commission for Europe
UNIDO	United Nations Industrial Developement Organisation
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	A combination of V2I and V2V
VTS	Vessel Traffic Services
WMU	World Maritime University

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Under the overall guidance of Cleopatra Doumbia-Henry, President of World Maritime University, the *Transport 2040: Automation, Technology, Employment - The Future of Work* report was prepared by a team comprising Jens-Uwe Schröder-Hinrichs and Dong-Wook Song (Co-Principal Investigators), Tiago Fonseca (Chapter 3), Khanssa Lagdami (Chapter 4), Karsten Loer (Chapter 1) and Xiaoning Shi (Chapter 2).

The report benefited from major substantive contributions from WMU faculty members Laura Carballo, Henning Jessen, Michael Manuel, Max Mejia as well as former colleagues Michael Baldauf, Armando Graziano, Adrienne Mannov and Peter Aske Svendsen.

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The research team benefitted from insight gained through participation in relevant meetings of UN institutions and would like to recognize IMO (Maritime Safety Committee, Sub-Committee on Ship Systems and Equipment), UNCTAD (Multi-year Expert Meeting on Transport, Trade Logistics and Trade Facilitation), UNECE (Inland Water Transport Working Party).

Eurostat shared data for this report, which is highly appreciated.

This report is the result of almost two years of intensive research that would not have been possible without the many comments, recommendations, inputs etc. by so many partners in international organizations, government agencies, industry and academia. To mention them all is not possible. However, their help is gratefully acknowledged.

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EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

The world is interconnected through global trade on the basis of a transportation industry striving to be more and more efficient. Every year 62.7 trillion tonne-miles of cargo are transported around the world. At the same time, new technologies and automation are displacing some jobs and creating new ones, thereby impacting employment in general. This has led to a wide discussion about the consequences of automation and technology and the effects that this may have for society at large. Governments, the business sector, trade unions, regulatory bodies and other stakeholders have a keen interest in the discussion of what the consequences of the Fourth Industrial Revolution will be, and how society at large can be prepared for the transformations that may arise from further introduction of advanced technologies and automation.

This report is intended to address the issue of how transportation will change as a result of more technologies and automation. The study that provided the data for this report is the result of intensive research conducted by an interdisciplinary team of experts with input from academia, industry and regulatory bodies during the last 18 months. The research undertaken forecasts and analyses trends and developments in all four modes of transport up to 2040 with a special emphasis on jobs and employment.

This report is based on four pillars: a forecast of technologies; a forecast of global trade and transport; an analysis of the labour force involved in transport; and the development of country profiles that can be used to illustrate the local context for the introduction of technology and automation in a specific country. In this report, we conclude that the introduction of automation in global transport will be evolutionary, rather than revolutionary. While it affects mainly medium- and low-skilled groups, technological change is impacted by local factors. Despite high levels of automation, qualified human resources with the right skill sets will still be needed in the foreseeable future. This conclusion is based on four key findings.

KEY FINDINGS

1 Economic benefits, demographic trends and safety factors are catalysts for automation; but in many areas of global transport the pace in the introduction of automation will be gradual.

2 The increasing volume of trade leads to more demand for transportation in the future, while regional changes in transportation patterns are expected.

3 With the gradual pace in the introduction of technology and the increased volume of trade, their effects on employment are predictable. Low- and medium-skilled workers will be exposed to the high risk of automation. However, the pace of introduction and diffusion of technologies will depend on differences in the development stage of countries and their comparative advantages.

4 Automation and technology are influenced by the local context. The assessment of individual country profiles shows that countries and regions are not at the same level of readiness to adopt new technologies and automation. An analysis of relevant key factors highlights the gap between developed and developing countries.

SUSTAINABLE DEVELOPMENT GOALS

This study has been undertaken in furtherance of the purposes and objectives of the United Nations Sustainable Development Goals. It addresses the following Sustainable Development Goals in particular:

1 WHICH NEW AND EMERGING TECHNOLOGIES WILL BE INTRODUCED IN GLOBAL TRANSPORT?

Across industries a number of trends have been evolving around digitalisation, increased levels of interconnectivity in production processes and advanced levels of automation. The implementation of these technologies has already started in many segments of the transport chain and will continue to have effects on all transport modes in the future.

Evolving technology trends can be discussed in the context of four technology clusters, addressing both the operation and maintenance of vehicles and the transport infrastructure, but also front-end customer service. Technologies within those clusters are reviewed with respect to their technical feasibility, the economic benefits they provide and the regulations and policies that need to be in place. The following conclusions have been reached based on the analysis of these clusters.

FOUR CLUSTERS OF NOVEL TECHNOLOGIES	
1	**Automation of vehicles and infrastructure** e.g. autonomous commuter trains, automated ships and airplanes, cranes, control centers
2	**Maintenance of vehicles and infrastructure** e.g. condition-based maintenance, inspection drones, repair robots, additive manufacturing of spare parts
3	**User interfaces for customers and equipment operators** e.g. chatbots for travel advice and ticketing, customer service robots providing information and catering
4	**New services** e.g. mobility as a service, cross-modal transport on demand, availability-oriented business models

1.1 THE INTRODUCTION OF AUTOMATION WILL BE EVOLUTIONARY RATHER THAN REVOLUTIONARY

Automation and new technologies will be introduced progressively in all transport sectors, but with sector-specific differences.

In the aviation industry, annual labour productivity has been growing faster than the overall economy. In addition to technological progress and automation, the growth rate has been the result of an increase in demand and change in the industry structure, such as the growth of low-cost carriers. Labour productivity in the airport sector appears to be more volatile than in the airline sector.

In maritime transport, the adoption of novel technologies tends to occur at a slower pace. Indications are that agreed international guidelines and regulations regarding autonomous transport are unlikely to be achieved within the next decade. However, if a strong economic benefit is expected and social acceptance exists, highly automated transport solutions could be implemented at the regional level and governed by national legislation or bilateral agreements among adjacent countries.

With respect to road-based transport, the introduction of these technologies and automation is likely to be evolutionary. In the case of transportation network companies in comparison to taxis, a much more immediate and disruptive effect may occur for certain uses, e.g. urban-shared mobility.

In rail transport, it can be assumed that using existing technologies could solve most of the technical and functional issues regarding fully automatic train operations.

Challenges that need to be resolved in all modes of transport are mainly operational and legal ones. Within the next 10 to 15 years fully autonomous operations are expected to become possible with the technical and legal barriers having been resolved. While the above trend indicates a gradual introduction of technology, disruptive technologies may emerge in selected sectors, e.g. airport passenger operations, customer and sales services, passenger security check, luggage and cargo logistics, taxis, local buses and, in the case of Europe, in the train control system.

1.2 BEYOND LONG-TERM ECONOMIC BENEFITS AUTOMATION IS TRIGGERED BY DEMOGRAPHY, SAFETY AND EFFICIENCY

Technology and automation are often triggered by the safety and efficiency concerns of operations, and not always motivated by reducing labour costs. In particular, in emerging technologies requiring interconnected systems there is a strong emphasis on ensuring the safety and security of operations. However, in some transport modes, such as the road freight sector, labour costs are regarded as an important element in business cases related to autonomous and highly automated transport.

Automation is often used as an argument to respond to demographic challenges in some regions of the world. For instance, in Europe an ageing workforce has created a mismatch between labour supply and demand. In response, more automation has been introduced to the European rail industry to outweigh the consequences of a labour market mismatch, while maintaining high levels of safety. At the same time, capacity, punctuality and efficiency have increased, while costs and emissions have been reduced – resulting in improved competitiveness of the railway transport.

Most notably, safety aspects are frequently promoted when automation and technology are discussed. Autonomous or remotely controlled devices reduce the exposure of transport workers to hazardous environments. Examples include exoskeletons that assist workers in lifting and moving heavy items; remote controlled cranes that can be operated from a safe distance; and airborne and underwater drones which make it possible to inspect and repair parts of ships and offshore structures that are difficult to reach by inspection workers.

Apart from the safety aspects, efficiency is an important factor for the introduction of technology and automation. Innovations that allow for higher levels of efficiency are given high priority due to increased competition across all transport modes.

1.3 IN MANY AREAS AUTOMATION IS LIKELY TO RESULT IN A SHIFT OF THE WORKFORCE, NOT IN LABOUR REDUCTION

The objective of optimization in transportation is related to efficiency gains. Increased levels of technology and automation will contribute significantly to this objective.

In transportation, the highest potential for automation is in low-skilled jobs, which are intensive on predictable physical activities and data processing; therefore those jobs face a high risk of being impacted by automation. At the same time, the further introduction of automation will also create a demand for new types of jobs, such as remote operators, worldwide operating maintenance crews and mobility-as-a-service providers. As a result, the demand for labour will not completely disappear, but the requirements and skills needed for individual jobs will change.

For further predicting the impact of technologies and automation on the global labour demand for transport workers, projections and trends in global trade are needed to complement the discussion.

2 HOW WILL GLOBAL TRANSPORT DEVELOP UNTIL 2040?

Following the identification of technology trends, an evaluation is made of the development of global trade and transport. Experience shows that, despite increasing levels of technology introduced during the last decades, no decline in employment was noted as a result of an increasing demand for transportation. To assess the consequences of the further introduction of technology and automation, it is therefore important to understand how global trade will develop further. This applies in particular to the trade patterns and modes of transport used in global trade. The research undertaken has led to the following conclusions.

2.1 OVERALL THE TRANSPORT VOLUME IS EXPECTED TO INCREASE, BUT AT A DECREASING RATE

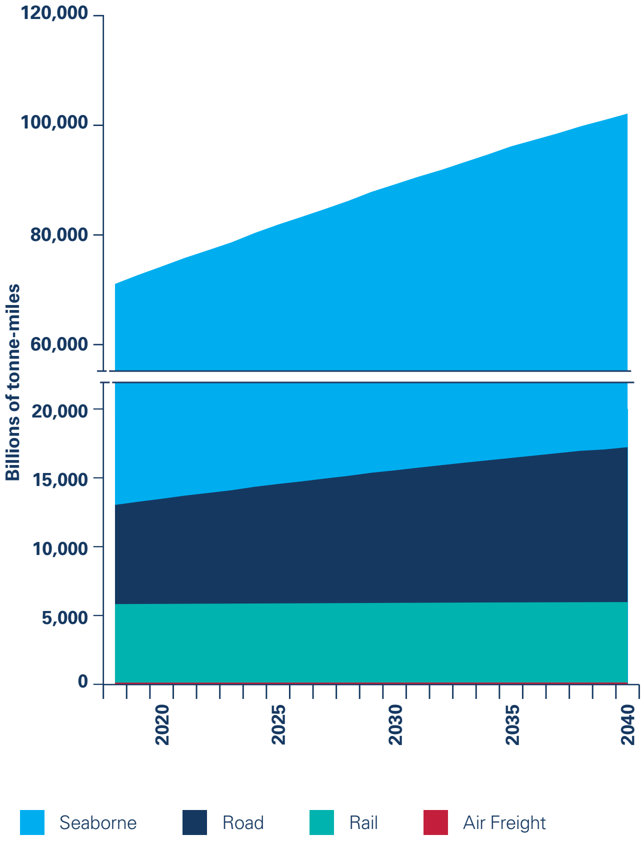
The demand for transportation is primarily in response to the economic environment and population growth. Historically, there has been a close correlation between the growth in the gross domestic product (GDP) and the transport volume, which means that economic activities and trade are among the main drivers of the demand in transport. This pattern is confirmed in this study.

From the perspective of the economy, the growth in GDP per capita has a positive effect on the volume of all freight transport. Even though the global GDP slowed down to 3 per cent in 2015 and 2016, the global GDP growth rates show an increase of 2.2 per cent to 3.2 per cent during 2017-2022. In respect of population, a higher population results in increasing trade demand. According to the projected population released by the UN[1] the world population is growing, but at a slower pace than in the past. It is estimated to reach 8.1 to 9.0 billion by 2040.

Regarding volume per commodities categories, it should be noted that as a result of international activities to mitigate climate change, renewable energy in general will be prioritized. As a consequence, the transportation of oil and related products will be reduced after 2030. Therefore, moving from 2030 to 2040, our projection shows that demand for maritime transport is likely to increase at a less rapid pace – with the growth primarily in non-energy commodities. However, it is expected that the slower growth in oil and related products after 2030, will be offset by a faster increase in trade volumes of finished and semi-finished containerisable products.

With respect to the volume per transport mode, aviation freight and passenger transport are both increasing at moderate rates. Seaborne trade and road transport enjoy a relatively high growth rate, but the growth rate itself is decreasing. It is forecasted that overall trade, measured as tonne-miles, will experience a 2.2 per cent annual growth over 2015-2030 and a 0.6 per cent annual growth rate per year after 2030. The growth rate will decrease afterwards until 2040, although growth will still occur (Figures 0.1 and 0.2). This means that an increased demand for transportation is expected until 2040.

FIGURE 0.1 Global transport turnover: projected development to 2040



Sources: World Bank, UNCTAD, International Road Federation, Institute of Shipping Economics and Logistics, DNV GL, WMU analysis and forecast

Note: Air Freight turnover is significantly lower thus not easily visible at the bottom of the graph (125.98 billion tonne-miles in 2018 and 132.75 billion tonne-miles projected to 2040).

[1] United Nations Department of Economic and Social Affairs Report: World Population Prospects: The 2017 Revision.

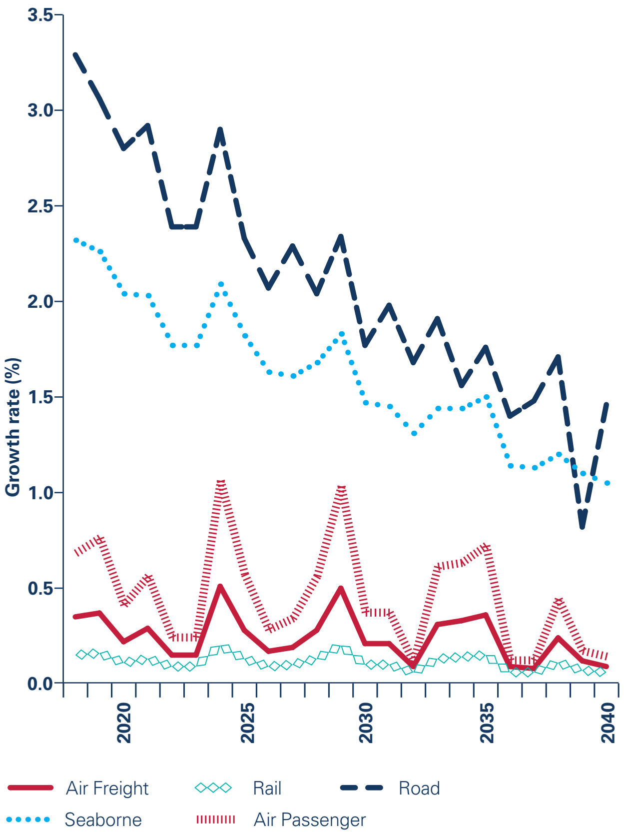
2.2 A NEW PATTERN OF TRANSPORTATION ROUTES WILL BE EMERGING

Turning to transportation routes and countries along these routes in coming years, one important factor to take into account is that the growth rate in China may decrease with time. Another factor is that growth rates for many of the developed countries may differ. France and Germany, for example, will decrease their current level of transport demand, while demand in others, like the United States, is expected to grow until 2040. Emerging economies, such as those of Mexico and India, may enjoy higher growth rates since trends in transportation follow trading patterns.

New and emerging patterns of transportation routes will be reflecting the volume in global trade; seaborne transport will still remain the dominant mode of transport for world trade. Today, seaborne transport accounts for more than 80 per cent of international trade in terms of tonne-miles. In other words, deep-sea cargo-carrying ships dominate transport services, and four-fifths of vessel traffic is currently deployed in the northern hemisphere serving the West-East trade routes.

In line with the new pattern of transportation routes, vessel traffic will see an increase in the Indian and the Pacific Oceans, and seaborne transport growth is likely to be focused in the Asia and Indian Ocean regions, thereby highlighting the importance of Asian trade. Because of the changes in trade routes resulting in the growth of Asia's share in global trade, the transport services facilitating this trade will also increase in volume in those regions.

FIGURE 0.2 Growth rates in global transport: projected decrease to 2040



Sources: World Bank, UNCTAD, International Road Federation, United States Census Bureau, WMU analysis and forecast

2.3 IMPROVED PRODUCTIVITY EXPECTED FROM TECHNOLOGY ADVANCEMENTS LEADS TO MODAL SHIFTS AT THE REGIONAL LEVEL

An important concern is that, to some extent, international shipping may be substituted by other transportation modes. This substitution is not foreseen to happen, however, as far as long-distance maritime transport is concerned, maritime transport still remains the leading mode in terms of the scale and volume of goods being carried.

In general, transport services will continue their impetus to achieve greater efficiency by reducing costs, improving utilization, lowering fuel consumption, increasing carrying capacity and deploying new technologies. Based on these, key concerns that could trigger game-changing modal shifts are energy use, emission policies, environmental awareness and technology development in transport. Figures from two regions are given to illustrate these modal shifts.

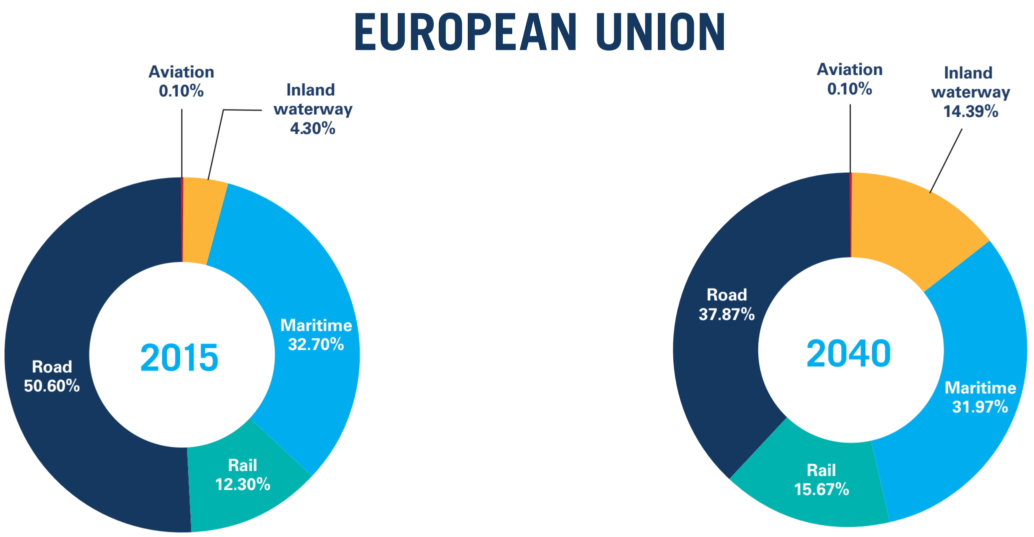
In the European Union (Figure 0.3), the percentage share of inland waterway navigation together with rail transport in the transport sector is forecasted to increase as a result of the development of technology, emission control policies and renewable energy policies. For instance, by 2040, the inland waterway transport system is expected to increase up to 14.4 per cent in 2040 compared to 4.3 per cent in 2015. For its part, rail transport is expected to increase up to 15.8 per cent in 2040 compared to 12.3 per cent in 2015. Conversely, road transport will decrease. However, such trends must be seen in a regional context and will need to be examined further.

ASEAN[2] countries (Figure 0.4) have experienced an increase of rail and waterborne freight movements over the last years. Historically, the inland waterway transport mode held an extremely low market share and was the least developed mode of transportation in terms of volume. The situation is expected to be changed in future, since the modal shifts in ASEAN countries will be led by emission-control policies and facilitated by infrastructure investment. More specifically, from 2015 to 2040, ASEAN might expect approximately 19.1 per cent of the total freight to be moved by rail, previously transported by road. During the same period, ASEAN might also expect to observe substantial increases in maritime transport including 5.6 per cent by inland waterways and 19.8 per cent seaborne. By then, waterborne freight to be carried would be approximately 0.8 billion tonne-miles. Subsequently, the projected road transport might decrease to 53.5 per cent by 2040, a significant drop from the current 91.0 per cent.

[2] ASEAN (Association of Southeast Asian Nations) includes Indonesia, Thailand, Vietnam, Singapore, Malaysia, Philippines, Myanmar, Cambodia, Laos, Brunei.

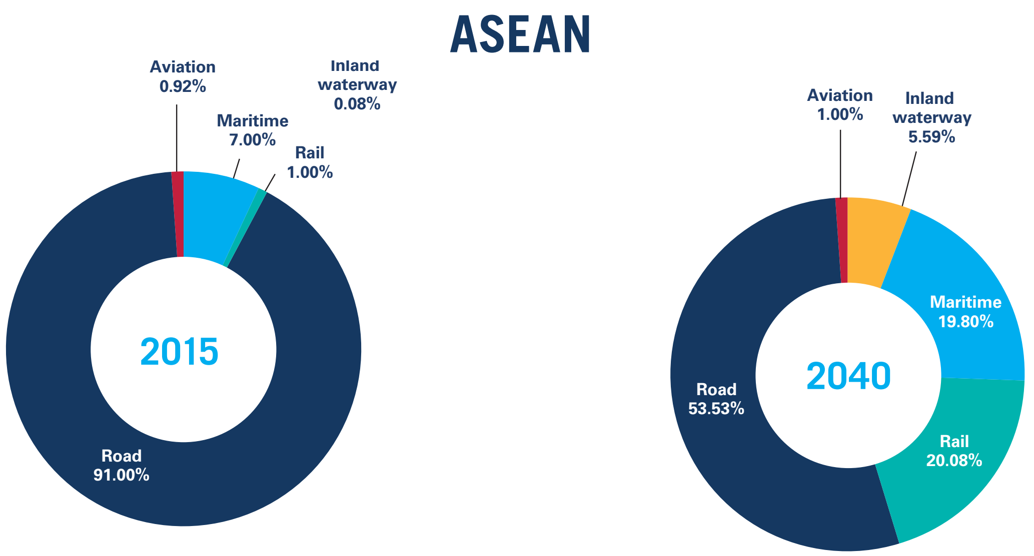
Our transport forecast highlights a situation that, while a familiar one, is a sector that has undergone significant changes, including the introduction of new technologies. Because technology enables quicker and more economic transport, it causes changes in trade patterns and modal shifts. It also influences employment whose professional categories will change as a result of shifting patterns in trade and modal shifts. This trend is highlighted in the next section.

FIGURE 0.3 Modal shifts in the EU (2015 and 2040)



Sources: Eurostat, WMU analysis and forecast
Notes: Figures relate to freight only. Computations based on tonne-miles. Aviation and maritime cover only intra-European movements of goods.

FIGURE 0.4 Modal shifts in ASEAN (2015 and 2040)



Sources: ASEAN StatsDataPortal, WMU analysis and forecast
Notes: Figures relate to freight only. Computations based on tonne-miles. Aviation and maritime cover only intra-ASEAN movements of goods.

3 WHAT ARE THE EFFECTS ON THE TRANSPORT LABOUR FORCE?

The third pillar of the analysis relates to a sectoral assessment of the transport sector labour force. The overview is one of the first to focus on this topic in transportation and covers almost 60 per cent of the world labour force from more than 70 countries. This assessment contributes to the discussion of how further technology and automation will affect the current and future jobs of transport workers.

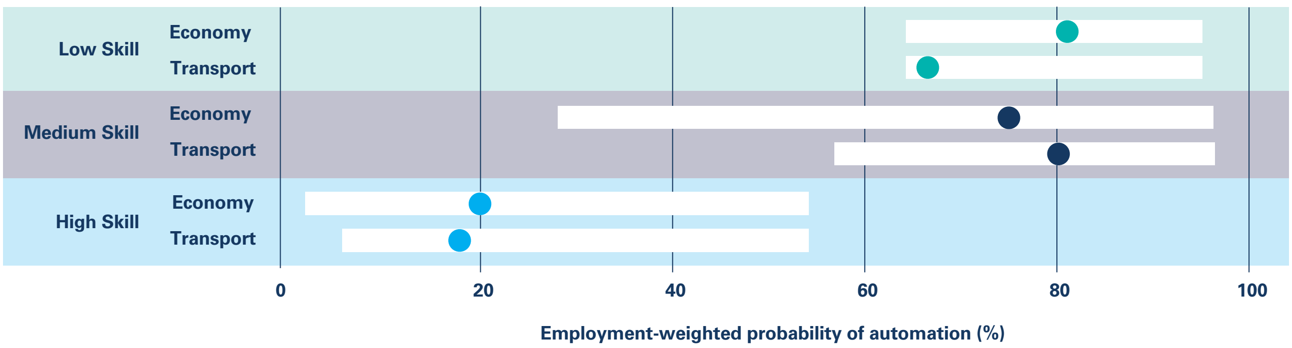
3.1 TRANSPORT HAS A HIGH POTENTIAL FOR AUTOMATION, LIKE OTHER INDUSTRIES, BUT AT SLOWER ADOPTION RATES

Research undertaken shows that transport workers face a similarly high risk of automation as their counterparts in other industries. The foreseeable advancement in automation technologies, such as artificial intelligence, mobile robotics, together with the declining price of computing power, is likely to have a similar impact on the tasks of workers across most industries. Figure 0.5 below shows the potential for automating tasks by 2040 among different skill groups. On average, the transport sector has a similar potential for automation as other industries, especially for the low- and medium-skilled groups of workers. The technologies and related applications to be introduced in various industries will also affect job profiles in transportation.

However, our research indicates that the pace through which the introduction of automation technologies takes place varies from sector to sector. Historical trends show that automation of routine-based tasks has led to the decline of middle-skill jobs, forcing those workers in the middle to shift to low-skilled and low-paid jobs. Only a small share of workers has been upgraded for high-skilled and high-paid jobs. The introduction of more advanced automation technologies, such as machine learning, can open the way to the automation of a wider range of tasks, thereby amplifying the downgrading effect of automation technologies on jobs and mid-level workers.

A closer look at the tasks involved in different jobs carried out by transport workers shows similarities across task profiles for sea, land and air transport in terms of the complexity and frequency of the tasks involved. Based on a composite task measurement indicator, it shows that tasks associated with rail transport are less prone to automation (higher score), while passenger road transport is the most likely to be automated (lower score). The potential for deep-sea transport is similar to that found in air transport. Task profiles are more diverse within the supporting activities of a specific transport mode, such as cargo handling in ports or airports. Supporting activities for road freight and deep-sea transport have the greatest potential for further task automation (lower score), while further automation is more difficult to be achieved in the supporting activities for rail transport (higher score). The variance found across tasks indicates that some industries will experience automation earlier than others, even when it relates only to their technical feasibility, that is to say, from the point of view of using current or foreseeable technologies to automate tasks.

FIGURE 0.5 Automation potential in relation to skill groups in transport



Sources: Frey and Osborne. Tech. Forecast. Soc. Change. 114 (2017), BLS, ILO, Eurostat, WMU analysis

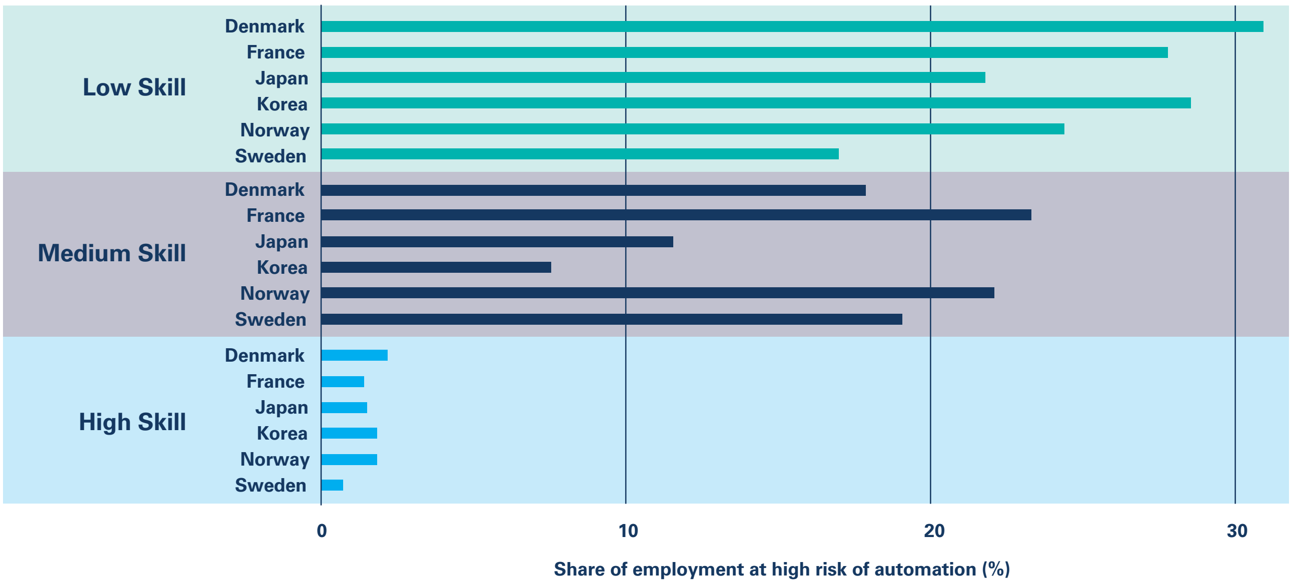
3.2 AUTOMATION TECHNOLOGIES HAVE THE POTENTIAL TO REDUCE THE GLOBAL DEMAND FOR TRANSPORT WORKERS

The potential for reducing the demand for transport workers as a result of the introduction of technology varies among different transportation modes. Foresight simulations undertaken for aviation, road and rail, show a potential decline in employment due to increasing technology use. However, estimates reflect only a decline due to technology implementation, that is, they do not take the growing demand for transport into account, as forecast in Chapter 2. Such an expansion of demand has the potential to outweigh and further increase the current labour demand.

Similarly, foresight simulations conducted for maritime transport show that the introduction of highly automated ships will lead to a decrease in the global demand for seafarers by 2040 vis-à-vis the baseline projection based on current technology. The introduction of highly automated ships[3] can reduce the global demand for seafarers by 22 per cent. The simulations show that such effects are not compensated by the increase in volume of seaborne trade projected for 2040, and they reduce the effect of automation on demand by 8 percentage points. Despite the decline, it is important to note that, for the period under analysis, all our simulations point towards growth in the demand for seafarers from 2020 to 2040. In absolute numbers, the number of seafarers required by 2040 is expected to be significantly higher than its current level. However, what technology is expected to do is to slow down the increase in the number of seafarers needed to carry out global trade.

Estimates for a group of countries participating in the Organization for Economic Co-operation (OECD) and Development Programme for the International Assessment of Adult Competencies survey show that between 6 per cent and 50 per cent of the low-skilled workers (e.g., dockers, baggage handlers) are exposed to the high risk of automation (more than 70 per cent of the tasks that are automatable), and their jobs will not exist in the current form by 2040. The same applies to the middle-skilled group (e.g., able seafarer, heavy truck drivers), where the share of employment at high risk of automation is as low as 7 per cent or as high as 23 per cent depending on the job responsibilities. What is consistent across countries, however, is the relatively small portion of jobs (not exceeding 2 per cent) of high-skilled workers that are at high risk of automation (Figure 0.6). The high-skilled group (e.g., ship officers, aircraft pilots and professionals) has the least estimated job losses resulting from the introduction of automation technologies. The estimated numbers refer only to their technical feasibility; the magnitude of the estimates could be reduced when considering factors other than technical feasibility (e.g., economic benefits, regulation and governance, or labour market dynamics).

FIGURE 0.6 Variation of automation risk across skill groups



Sources: Arntz, *et. al.* OECD Social, Emp. and Migration WP. 189 (2016), WMU analysis

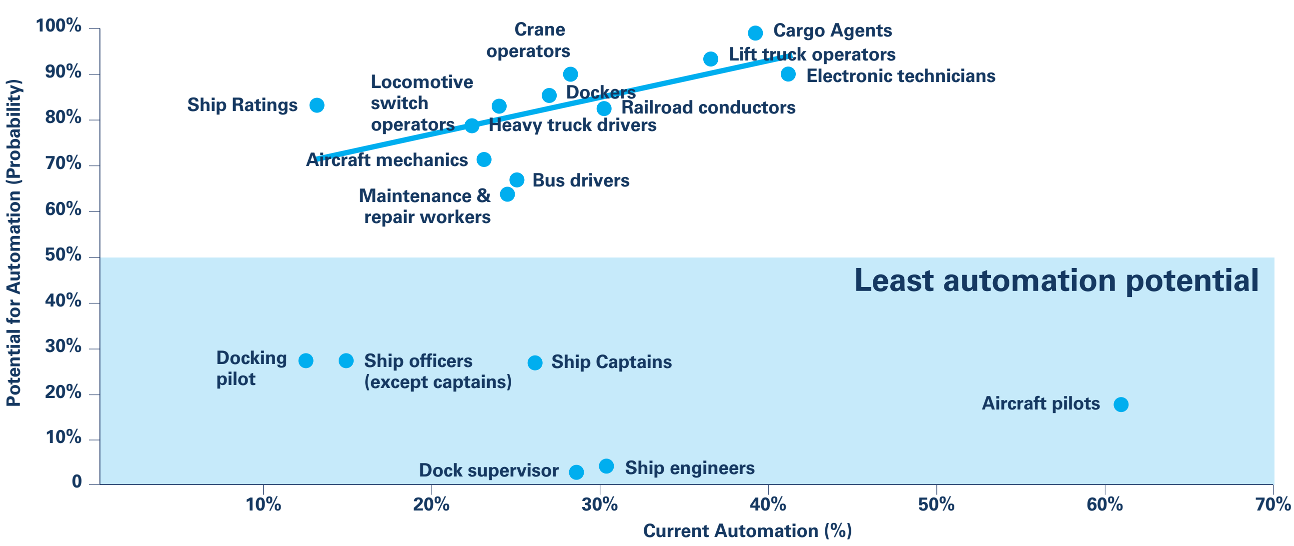
[3] A highly automated ship refers to a vessel whose technical system can take most decisions and actions. Based on the degree of autonomy, the role of the human operator ranges from taking some decisions and actions, intervening and overriding, or engaging only if the systems make a decision to those ends.

3.3 THE IMPACT OF AUTOMATION ON THE TRANSPORT LABOUR FORCE VARIES ACROSS SKILLS AND TASKS

From a technical perspective - if one does not take into account the economics of automation - the current degree of automation can be considered a good predictor of future automation for the low- and middle-skilled occupational groups. Figure 0.7 shows that low- and middle-skilled jobs (e.g., dockers, crane operators or truck drivers) currently facing a high degree of automation have a higher likelihood of further automation, with the consequence that most tasks forming part of their job responsibilities will become obsolete. Naturally, the further introduction of automation technologies that is expected to make some low- and middle-skilled jobs redundant will vary from country to country as factors other than technical feasibility come into play. Conversely, this linear positive relationship between current automation and further automation does not apply to the high-skilled group (e.g., ship captains, officers and aircraft pilots). Figure 0.7 shows that current vehicle, infrastructure and systems design open the door for automation of tasks performed by low- and middle-skilled workers, whereas tasks performed by the high-skilled group are least prone to automation. For the latter group, automation and technology are often introduced to assist them, so that individuals can concentrate more on their core tasks. The objective is to complement their work rather than replace them, whereas for the other groups a large proportion of core tasks might be automated.

A review of the skills distribution across different geographical regions indicates that the reliance on medium-skilled labour across the industry sectors opens the door for automation, as automation technologies are primarily substituting tasks mainly performed by the low- and medium-skilled groups. In that regard, all regions have a relatively high risk of automation of work processes from a technical feasibility viewpoint. However, our analysis also shows that not all demographic groups are affected by automation in a similar way. Ageing and/or comparatively high-wage workforces face a greater risk of being impacted by a higher degree of automation, while the economic incentives for automation are less advantageous for younger and/or lower-wage workforces. Consequently, the variation in the socioeconomic and demographic composition of the different countries leads to variations in the implementation schedule of automation across different geographic regions, notwithstanding that a similar technical automation potential exists.

FIGURE 0.7 Automation potential for job profiles in transport



Sources: Frey and Osborne. Tech. Forecast. Soc. Change. 114 (2017), Occupational Information Network (O*Net), WMU analysis

4 WHAT IS THE IMPACT OF LOCAL FACTORS ON THE IMPLEMENTATION OF TECHNOLOGY AND AUTOMATION?

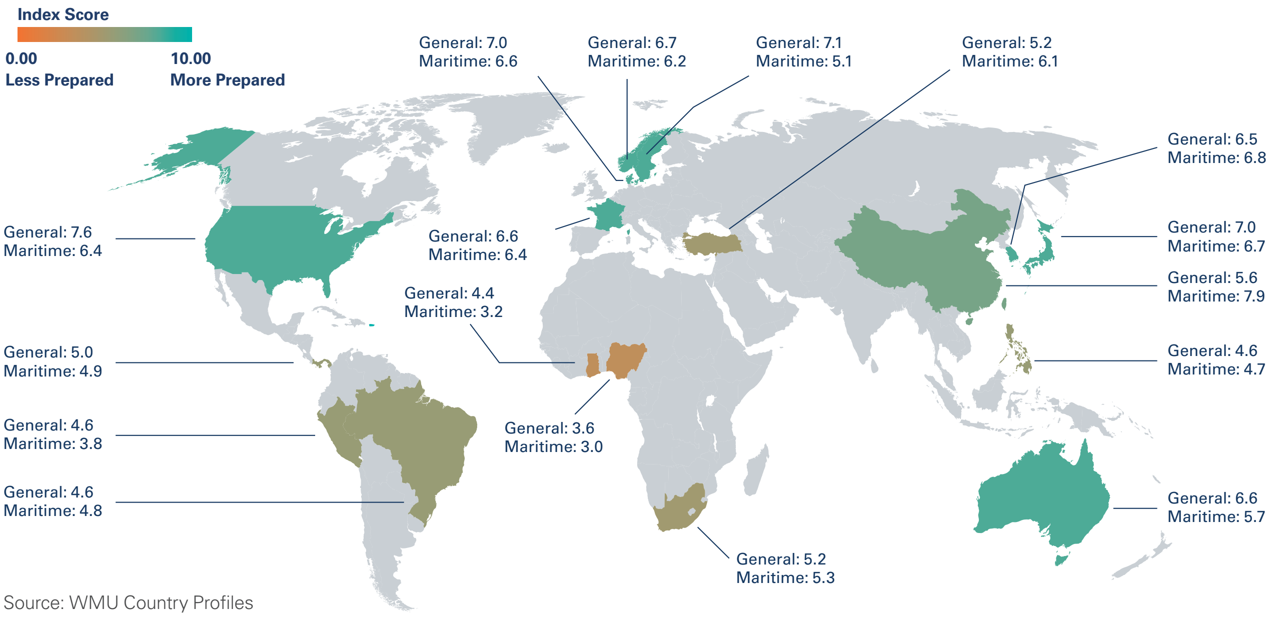
Automation and technological advances are driven by the local context. To provide a snapshot of the individual factors in a specific country, country profiles have been developed. The country profiles have been used in the context of 17 countries[4] to discuss the challenges and opportunities related to the further introduction of technology and automation in transport. A special emphasis was accorded to maritime transport in this section of our study.

4.1 AUTOMATION WILL BE DEVELOPED AND IMPLEMENTED AT DIFFERENT RATES IN DIFFERENT REGIONS

The pace and extent of introduction of new technologies and further automation vary from region to region. Countries and regions will experience the impact of new technology, but both its momentum and impact will vary. The change will depend on a number of factors. Regulation and human capital are just two examples. The pace of adoption also depends on the benefits that automation is expected to contribute to socioeconomic progress in a country. Technological change has always been regarded as an indispensable ingredient of development strategies throughout the world. In some countries, the necessary infrastructure and relevant business models do not exist, which delay the introduction of new technology and automation.

Based on the results of our research (Figure 0.8), countries with a higher readiness to introduce new technology and automation are located in Australia, East Asia, U.S. and Europe. African countries, as a bloc, are lagging behind in terms of technological advancement and investment, regulation, governance and infrastructure in all economic sectors, including in the maritime transport sector. Countries in South America are also in the same position.

FIGURE 0.8 Readiness level for the introduction of emerging and new technologies



Source: WMU Country Profiles

[4] 17 countries are: Australia, Brazil, China, Denmark, France, Ghana, Japan, Nigeria, Norway, Panama, Peru, Philippines, Republic of Korea, South Africa, Sweden, U.S. and Turkey.

4.2 THERE IS A READINESS GAP AMONG DEVELOPED AND DEVELOPING COUNTRIES IN THE MARITIME SECTOR

The successful introduction of high levels of technology requires significant investment and other inputs, such as education, training and research in order to provide suitable conditions to successfully introduce technologies and automation. In that regard, while some countries in our study are trying to become leaders in the field of automation and technology in the maritime sector and their maximum efforts are focused on building the requisite foundation, other countries will not rapidly introduce the emerging new technology because their priorities are developmental, or focused on meeting the basic needs of their population: food, healthcare and education.

4.3 MANY COUNTRIES HAVE NOT DEVELOPED LONG-TERM PLANS FOR AUTOMATION IN THE MARITIME SECTOR

Although a number of ongoing discussions about automation and further technological innovation are taking place in the context of the maritime industry, the maritime sector is still at an early stage of transformation. Many countries have not developed strategies for automation. In addition, while some countries are seeking to become leaders in a number of domains, for example, in the development of relevant regulations, infrastructure and competences, these countries are still at an early stage of setting up policies and strategies in response to anticipated developments in the industry.

In that regard, the international maritime community has just begun discussions about the regulation of autonomous ships. Many countries in our study are active in that regard, such as Australia, China, Denmark, France, Japan, Norway, Republic of Korea, Sweden and U.S. However, no country has to date unveiled a comprehensive strategy for maritime transport in 2040, one that combines regulations with innovation, competences and skills, infrastructure and future business models.

INTRODUCTION

INTRODUCTION

Industrialization and transport have always been in close association. Increased levels of production and new technologies developed for the industry at large have engendered new solutions and forms of transport. Transportation was one of the key enabling factors for globalization. Every year 62.7 trillion tonne-miles of cargo are transported around the world. Transport, like any other industries, is currently undergoing a lot of changes as a result of the introduction of new technologies with far-reaching consequences for all modes of transport. These changes are driven by increased use of automation and new technologies which have the potential to transform jobs and the structure of the labour force, as well as to accelerate skill shifts compared with the historical trend. Technological progress and innovation have occurred throughout history and changed its course, for example the Industrial Revolution in the eighteenth and nineteenth centuries.

This report focuses on providing evidence on the effects of automation and new technologies on the global transport labour force by 2040. Currently, we are about to embrace what is now termed the 4th Industrial Revolution (4IR), which is characterized by the introduction of artificial intelligence, robotics, more and more interconnection, among other innovations. As this report focuses on the global transport sector, examples illustrating the transformative capabilities of automation and technology span from driverless trains already used in metros in different parts of the world, to truck platooning, or convoying, in road transport, which represents a new level of automation; from the technology for automatic baggage handling systems in airports to automated and semi-automated container terminals in ports. In the maritime sector, recent discussions about autonomous ships have triggered a number of activities at the International Maritime Organization (IMO). Equipment manufacturers have created the notion that automated ships could be operating in larger numbers in a few years.

The emerging contours of a transformational change and the level of automation have now reached a point where shifts in the nature of work have become visible and are part of public discourse in many countries. While the themes of innovation technologies and automation now being discussed conjure up notions of progress and a new age, they also connote elements of uncertainty and ambiguity. As a result, a number of questions are currently raised by various stakeholders in the transport sector. Issues discussed relate, as an example, to the drivers of automation and technology. While manufacturers present convincing arguments on the benefits, comprehensive and in-depth discussions and studies are needed to critically examine the potential implications of automation on jobs and the employment situation in general.

One point that needs to be considered in this respect relates to timelines for automation. For example, the technology may be available but there may be a considerable time lapse before its large-scale introduction. The extent to which these technologies might displace workers will depend on the pace of their development and adoption, economic growth and the growth in demand for work.

Aspects in this context refer to economic benefits and business models generated by new technologies and further levels of automation. It is often argued that higher initial costs for new technologies could be an obstacle for their implementation. As an example, the costs of building a ship with the required technology and redundancies for a remotely controlled operation might be higher than for a conventional ship. A global shore-side infrastructure system for monitoring and control will need construction, and expensive shore-side support required for maintenance, repairs and functions, tasks which seafarers from cost-efficient labour supply countries now carry out on conventional ships. Thus one must ask whether the additional costs of an autonomous ship, automated port or any other mode of transportation can be offset by substantial reductions in, or elimination of, crew or of labour costs? Another key element concerns what factors need to converge before automation and technology generates optimal economic results and with what social repercussions.

Turning to the issue of high-tech jobs, the automation and technology industries argue that technology will create high-tech jobs. However, what will be the number of those new jobs and what skills will be needed in order to effectively work with these new technologies? In this respect, questions related to the possibilities of retraining existing labour forces are of relevance.

At the global level, no uniform pattern exists in regard to the transport industry as the situation may vary from region to region and/or country to country. Automation may not be adopted in regions or countries simultaneously or on the same scale. On the one hand, increased automation in some countries may help to fill in the gaps arising from an overaged, retiring workforce. On the other hand, other regions with younger workforce may lack the prerequisites for large-scale automation.

The questions presented above are only a few of the many other issues that are currently debated in different fora. This report has therefore been commissioned in order to provide a thorough analysis of current trends in automation and technologies on the transport sector, and to assess in relation its implications on jobs and employment over the period up to

2040. The study that provided the data for this report is the result of intensive research conducted by an interdisciplinary team of experts with input from academia, industry and regulatory bodies during the last 18 months. The report is based on four pillars: a forecast of technologies; a forecast of global trade and transport; an analysis of the labour force involved in transport; and the development of country profiles that can be used to illustrate the local context for the introduction of technology and automation in a specific country.

Chapter 1 provides an overview of trends and new technologies, including automation that will shape the future work. A review of the stage of technologies across all transport modes is also conducted, including a forecast of selected technological applications.

Chapter 2 attempts to forecast trends in the transport sector by 2040 including projected volumes for aviation, rail, road and maritime transport, followed by an analysis on global trade and transport patterns based on global population trends and economic development. In addition, considering trends of technology and automation, a projection for modal shifts is also carried out for the European Union (EU) and the Association of Southeast Asian Nations (ASEAN) in order to highlight the interaction between technological advancement and regional modal shifts in transportation.

Chapter 3 provides an overview of the global transport labour force by analysing statistics from over 70 countries. The analysis was made to obtain a profile of the labour force involved in transport for different skill groups and to assess their potential for automation. At the end of the chapter, simulations for labour reductions due for select technological applications across all modes of transport are presented and analysed. Building on the data from the previous chapters the simulations forecast how labour can be affected due to emergence of certain technological applications and, in the case of shipping, also the increase in international trade.

By taking a national perspective, the maritime technology country profiles in Chapter 4 aim to give an overview of countries' positions vis-à-vis emerging and new technologies by highlighting five indicators that measure a country's readiness for automation by 2040. As opposed to the global overview provided by the previous chapters, the country profiles can be regarded as a tool of measurement of the local (country-level) present readiness for the use of emerging and new technologies; and as a facilitator for future actions in the selected countries.

Four case studies are introduced at the end of the report in order to illustrate the complex nature of further introduction automation and technology in transport, they also highlight the implications on jobs and employment for specific examples of technologies in different modes of transport.

Finally, the last section of the report presents the conclusions and recommendations and assesses how automation and new technologies will impact the transport labour force in the years ahead. Recommendations for Governments, the business sector, trade unions, regulatory bodies and other stakeholders are presented because preparedness for the pace of change and innovation to come and its disruptive powers for low-skilled and medium-skilled workers has societal implications, notwithstanding the gains in efficiency, safety and productivity that automation and technology bring. All this requires regulatory and legal action.

The interdisciplinary research at WMU benefited from access to the United Nations (UN) institutions and in particular the International Maritime Organization (IMO), International Labour Organization (ILO), United Nations Conference on Trade and Development (UNCTAD), United Nations Economic Commission for Europe (UNECE) and World Bank. The team was therefore able to work with a number of these relevant institutions who work on issues relevant to this study. This facilitated addressing the complex nature of this project in a comprehensive manner. The team could furthermore rely on contributions from government institutions, industry and academia. This provided opportunities for a deeper understanding of all the facets involved in the current discussions about automation and technologies in transport. It is hoped that this report can therefore be considered as providing an impartial basis for further discussion about automation, technology and employment in the transport sector and help to ensure informed policy formulations to deal with the implications.

CHAPTER 1

TECHNOLOGY TRENDS

1

SUMMARY

Technological innovation is bringing about rapid change to industries. This is reflected in several trends that are emerging around digitalization, in the increased interconnectivity of processes and in advanced levels of automation. The adoption of these processes is already underway in many segments of the transport chain, and in the future they will continue to impact all transport systems.

This chapter provides an overview of trends and novel technologies, including automation, that will have an effect on future work in transport.

A review of developments across all transport modes highlights three general findings:

1. **The introduction of automation will be evolutionary rather than revolutionary.**
2. **In many areas automation is likely to result in a shift of the workforce, not in labour reduction.**
3. **Beyond long-term economic benefits automation is triggered by the effects of demographics, safety and efficiency.**

1 INTRODUCTION

In the past century, the transport industry has successfully adapted to technological advances a number of times. Some technologies led to gradual changes, others led to disruptive changes. For example, in maritime transport, the transition from sail to steam engines, and later to combustion engines, resulted both in the need to bring professionals with new skills aboard, namely, stokers and engineers, but also in the need to provide new types of services, such as the supply of coal and fuel in ports along the main trade routes around the globe.

Looking back to the 1950s/1960s, the introduction of containers resulted in major changes in job profiles, e.g. general cargo handlers became container lashing crews, and in operations, e.g. shortened turnover durations in ports took place. These trends also impacted ship crews who now had limited possibilities for shore leave.

In air transport, the transition from balloons and airships to propeller aircraft, and later from propeller to jet engines, opened new transport routes and business models for accelerated transport of goods and passengers. However, the newly introduced technologies resulted in much higher qualification requirements for flight crews and maintenance personnel. Automated flight control systems, in addition to navigational tasks, also performed many tasks that were previously performed by flight engineers; and the "glass cockpit" significantly changed the occupation of flying from manual to observatory tasks.

Similarly, in road transport, the introduction of support systems, such as lane control and distance control, took manual driving responsibilities away from truck drivers. Finally, in railway transport, the switch from steam to diesel engine and the introduction of electrified tracks and electric engines posed new challenges to operating crews and maintenance crews.

Many of the changes in the past were focused on individual transport modes and/or job profiles. With the advent of the megatrend in digitalization and due to an increasing level of interconnectness in global transport processes, the upcoming wave of technology would affect all transport modes on many different levels of operations, from planning to execution. Drawing on parallels from the past, this situation is only preceded by the advent of revolutionary technologies, such as the steam engine, electricity and the advent of computers (Manyika et al., 2017).

In this chapter, technology trends that are currently on the horizon are reviewed, and the implications of these developments for the nature of future transport work are presented.

1.1 CLUSTERS OF TECHNOLOGICAL TRENDS

With regard to transport activities, the evolving trends in technology can be grouped into clusters (see Table 1.1). They address both the operation and maintenance of vehicles and the transport infrastructure and "front-end" customer services. Subsequent sections discuss trends and technical enablers in each cluster and provide examples for possible implementation in each transport mode.

TABLE 1.1: CLUSTERS OF TRENDS RELATED TO NOVEL TECHNOLOGIES AND AUTOMATION

Cluster 1 **Core automation functionalities of vehicles and infrastructure**	**Cluster 3** **User interfaces for customers and equipment operators**
Cluster 2 **Maintenance of vehicles and infrastructure**	**Cluster 4** **New services**

INFOBOX 1.A DIGITALIZATION, AUTOMATION, LEVELS OF AUTONOMY AND AUTONOMOUS AND UNMANNED SYSTEMS

Digitalization is the process of introducing digital components into systems and processes thereby enhancing or replacing physical components by electronic systems (e.g. steer-by-wire).

The term **automation** describes processes and systems i.e. mechanical devices or electronic devices, which are often computerized and that execute certain operations by a specific method without human control, but which are often supervised by humans. If the system has control functions that can use different options to solve selected classes of problems, the system is said to be **autonomous** (Rødseth and Nordahl, 2017).

Depending on the degree of labour that needs to be performed by human operators in collaboration with an autonomous system, the system is assigned a **level of autonomy**. Across industries, a range of taxonomies of levels of autonomy has been developed (see Annex A). For example, a taxonomy that has been broadly applied in the maritime industry was proposed by Lloyd's Register (2017) (see Table 1.A).

Finally, **unmanned vehicles** are a special case where the operating crew is not on board the vehicle, and which is then either remotely controlled, or operated autonomously.

Table 1.A: Lloyd's Register's taxonomy of autonomy levels in maritime transport

LEVEL OF AUTONOMY (AL)	DESCRIPTION
AL 0: Manual	No autonomous function. All action and decision-making performed manually (n.b. systems may have level of autonomy, with human in/on the loop.), i.e. human controls all actions.
AL 1: On-board decision support	All actions taken by a human operator, but decision support tool can present options or otherwise influence the actions chosen. Data is provided by systems on board.
AL 2: On & off-board decision support	All actions taken by a human operator, but decision support tool can present options or otherwise influence the actions chosen. Data may be provided by systems on or off-board.
AL 3: 'Active' human in the loop	Decisions and actions are performed with human supervision. Data may be provided by systems on or off-board.
AL 4: Human on the loop, operator/supervisory	Decisions and actions are performed autonomously with human supervision. High impact decisions are implemented in a way to give human operators the opportunity to intercede and over-ride.
AL 5: Fully autonomous	Rarely supervised operation where decisions are entirely made and actioned by the system.
AL 6: Fully autonomous	Unsupervised operation where decisions are entirely made and actioned by the system during the mission.

Source: Lloyd's Register, 'LR Code for Unmanned Maritime Systems', Lloyd's Register, 2017.

2 CLUSTER 1: CORE AUTOMATION FUNCTIONALITIES OF VEHICLES AND INFRASTRUCTURE

Some operations of vehicles and infrastructures include tasks that are either complex and hard to control by human operators, or repetitive or monotonous. Such tasks promote human error. Indeed, they are frequently cited as contributing factors in human error-related accidents across many industries. At the same time, humans present in a system at the time of evolving critical situations have often managed to avert accidents (Reason, 2008). The aims of introducing automation include assisting operators of vehicles and infrastructure in conducting tasks that could be error-prone when performed by humans, and at the same time freeing operators' mental resources to focus on strategic tasks.

2.1 VEHICLE OPERATION

Automation can assist operators of transport vehicles in different ways. Assistive vehicle functions provide support with respect to single functionalities, e.g. track and lane keeping, speed control and fuel saving, or a combination thereof. In the future, an increase of autonomous vehicle operations will take place, where the automated system takes over control for a certain phase of the journey, either with or without human supervision. For instance, navigational autopilots consider safety, economic and environmental goals during the journey. The safe and reliable operation of such systems requires a range of sensors that measure the surroundings of the vehicle (positions, obstacles, pathways), reliable and secure networking between vehicles and infrastructure (V2X) and data processing capabilities (e.g. sensor data fusion and artificial intelligence (AI) aboard the vehicle.

Autonomous vehicles will first be introduced in specific trades and in manageable areas, such as dedicated railway tracks (such as metro trains, e.g. Figure 1.1, right column), land areas and waterways, in ports, warehouses and in specific city areas (Fruth and Teuteberg, 2017). In many applications the need for drivers will probably not disappear; rather the role of the driver or operator will evolve into that of a "vehicle and service agent" (Bekiaris and Loukea, 2017). Therefore, in many areas automation will likely result in a shift of the workforce and not in labour reduction.

2.2 INFRASTRUCTURE OPERATION

In all transport sectors, control of the transport operations and infrastructure is moving towards centralized and interconnected operation centres, such as fleet operation centres (see Figure 1.1, left column), maritime vessel traffic service centres, remote tower air traffic control centres and railway control centres. In addition to the aforementioned systems that operate within a single transport mode, another challenging application are operations that organize cross-modal trades among two or more transport modes, e.g. smart ports[5] and rail/road interchanges.

Such centralized operations – whether for a geographically small area like a harbour or parts of a city, for larger areas such as inland waterways or parts of railway or motorway networks, or for global airborne or waterborne operations – require a technical infrastructure that provides a level of situational awareness to the controllers who need to make decisions remotely. This infrastructure consists of reliable sensors, good quality external data (e.g. weather data), data processing and timely, reliable and secure communication channels.

These centralized control systems evolve within a large system-wide modernization plan that incorporates automation systems, operational standards and protocols. They are designed and implemented in stages to progressively improve the safety, efficiency and predictability of transport systems.

Shore-based control centres make it possible to optimize the routing of ships, e.g. in response to environmental constraints (weather) and operational considerations (slow steaming, or availability of slots in canals, locks, berths). Nowadays navigational control can be applied by providing assistive information to ship crews, or in the future by direct remote control functions aboard the vessel (see Figure 1.1, left column).

[5] Examples of "smart ports": smartPORT Hamburg (www.hamburg-port-authority.de/en/hpa-360/smartport/), Smart Port Rotterdam (http://smart-port.nl), Singapore smart port challenge (https://www.pier71.sg/smart-port-challenge/)

FIGURE 1.1 Applications of digitalization and automation in maritime fleet support and rail passenger transport

▲ **SHORE-BASED SHIP CONTROL CENTRE**
(© Carnival Corporation)

▲ **KINKI SHARYO L500**
Train operating driverless on Dubai metro Red Line.

2.3 SUPPORTING FUNCTIONS

Beyond transport and control operations, a number of functions that support the work in the supply chain will be affected by emerging technologies and automation. For example, blockchain technology can improve trustworthy data transfer without the need for a central authority, e.g. for the verification of cargo manifests. Big data analysis can yield improved dangerous goods manifests, e.g. by mining information on past violations of customers. Innovative fast x-ray machines will make it possible to detect anomalies during container screening without delays. Airborne and underwater drones can support staff in surveying assets and cargo.

Connecting data streams from different transport modes and mining of "big data" will make it possible to process logistics information, e.g. customs, security, health and waste, more efficiently. Efficiency will be improved when common data structures are used by all stakeholders.[6]

[6] For example, consider the concept of creating a "national single window" (i.e. "an environment for collection, dissemination and exchange of vessel reporting information with a structured and commonly defined data structure, rules and management of access rights, which conform to relevant international, national and local legal requirements." (EC, 2016)

3 CLUSTER 2: MAINTENANCE OF VEHICLES AND INFRASTRUCTURE

The maintenance of vehicles and infrastructure is important to maintain safety. Maintenance operations can be hazardous for personnel; they are time-consuming, and for many means of transport, services need to be reduced or interrupted during the performance of maintenance work.

3.1 PREDICTIVE MAINTENANCE OF VEHICLES AND INFRASTRUCTURE

Similar to the current practice prevailing in the road, train and air transport sectors, in the future, in the maritime transport a large portion of maintenance work may be performed by personnel that will no longer be located aboard the vehicle, but in centralized service-hubs. Maintenance work can either be performed remotely from these hubs, e.g. software updates, or by highly specialized crews who reside in service centres around the globe and are dispatched on demand to the location where maintenance service is needed.

Advances in the development of sensor technology and reliable networks make it possible to closely monitor the condition of equipment aboard vehicles and in the transport infrastructure. In an analogous development to in-vehicle sensors, currently a vast number of sensors are embedded into the land-based physical infrastructure, including road surfaces, rails and switches, bridges and tunnels. This makes it possible to move from preventive maintenance, where the maintenance schedule typically is determined by average or expected life statistics, to more flexible maintenance schedules, based on predictions and measurements of the actual conditions of systems and infrastructure. For example, the U.S. Department of Energy has calculated that in the energy sector, through predictive maintenance, this task can be reduced by up to 30 per cent and business interruptions by up to 75 per cent (Sullivan et al., 2010).

Future predictive maintenance systems will increasingly make use of a wider range of "big" data. This data is not only obtained from vehicle and assets, but also from external operating conditions that have an effect on the individual vessel, such as cargo, waves, climate and weather conditions that were experienced during journeys. Predictions can be improved by creating a digital copy ("digital twin") of the vehicle and its systems. Digital twins[7] make it possible to explore aspects of assets, including layout and design specifications, and to perform various types of simulations (DNV GL, 2016), which help to predict when a critical breakdown may occur. This will enable operating crews to avoid critical breakdowns with a greater degree of certainty than today.[8]

Maintenance robots will assist crews in performing maintenance work on items that are hard to reach, e.g. aircraft surfaces, or that cannot be handled physically by humans, e.g. heavy parts and machinery aboard ships, in ports and on railways; or contaminated parts. Airborne or underwater vehicles ("drones") can perform potentially hazardous inspection and maintenance tasks, either by remote control or autonomously.

3.2 ADDITIVE MANUFACTURING OF SPARE PARTS

Just as a maintenance crew may not be present continuously aboard a vehicle, spare parts that may be required for maintenance or repairs also no longer need to be carried aboard the vehicle or sent long distance from manufacturers' sites. Manufacturers can employ additive manufacturing ("3D printing") to produce industrial quality spare parts on demand and in facilities located in different countries (Geissbauer, Wunderlin, and Lehr, 2017). The issue of distributing sensitive design and manufacturing data can be addressed via data encryption and blockchain technologies.

As the previous considerations indicate, the personnel that perform maintenance-related tasks may no longer be located in traditional locations, i.e. onboard the vehicle or in workshops. Instead, future maintenance personnel may be based in service hubs from where they can remotely perform maintenance tasks on vehicles or infrastructure, or a specialized crew will be dispatched to locations where the maintenance work needs to be performed. Either operators, equipment manufacturers or third party service suppliers will operate such service centres.

[7] For example, in the maritime industry, in May 2018 the "Open Simulation Platform" project was launched by Rolls-Royce Marine, the Norwegian University of Technology Science, the research organization SINTEF Ocean, the classification society DNV GL, the Joint Industry Partners Hyundai Heavy Industries, Kongsberg Digital, Vard and the Offshore Simulator Centre.

[8] For example, in the presentation "The Future of Smart Airport Technology Development and Job Policy" at the Air Transport Research Society World Conference in Seoul 2018, Joonki Lee (E&Y) stated that the use of digital twins for fault prediction at industry sites can lead to a 78 per cent fault reduction (4 July 2018).

4 CLUSTER 3: USER INTERFACES FOR CUSTOMERS AND EQUIPMENT OPERATORS

The advent of novel technologies will lead to an increased need for transport workers and customers to interact with novel types of machines. User interfaces need to ensure that the interaction between system users and machines is not only safe and effective, but also satisfying for the user (ISO 9241-11, 2018). Beyond screens and keyboards, a number of interaction technologies are maturing that will have an impact on future transport work.

Virtual reality, telepresence, augmented reality and mixed reality, in combination with digital twins and reliable data networks with sufficient bandwidth, make it possible to remotely operate vehicles or maintenance equipment such as robots and inspection drones; in the same manner, as tele-medicine already allows for remote examinations and operations.

With respect to customer services, chatbots are capable of processing written or spoken natural language and can provide consultancy services regarding travel and bookings via online chat or phone. Physical customer service robots provide services, such as tickets, refreshments or catering.

Mobile applications will provide user and consumer-centric solutions for information, bookings, payments and ticketing. Context-aware apps, in conjunction with information networks and augmented reality, can provide on-demand information supporting specific tasks, e.g. displaying to maintenance personnel technical details of the piece of equipment on which maintenance is to be performed; or offering travellers personal advice regarding the current phase of their journey.

In airports and railway stations, baggage handling automation facilitates luggage screening, conveyance, storage and retrieval, and loading and unloading functions. In some airports, the use of radio-frequency identification (RFID) further enhances automation by removing the need for manual bar code scanning. Self-service kiosks, which allow passengers to check in with minimum staff support, reduce customer queuing time and airport labour needs.

5 CLUSTER 4: NEW SERVICES

The interconnectivity of transport modes makes it possible for current stakeholders and new players to create novel types of services that address customer demands and those of transport service providers. Automation and the availability of real-time data can have an impact on the planning of transport services generally, including the necessary back-office processes. There is a large potential here for a breakthrough in efficiency and customer convenience and experience. Such an approach can make it possible to migrate from the current rigid time-table operation of transport modes, both in terms of time and routes, to a much more flexible on-demand service that is tailored to the needs of freight forwarders and passengers in terms of vehicle and trip characteristics (see Figure 1.2). Such approaches are possible even without vehicle automation, but by means of automation the economic benefit will become even more appealing; a trend already evident today in the road sector with tests and trials being carried out by tech sector companies like Waymo or Uber.

FIGURE 1.2 New planning services will make it possible to choose the best combination of transport modes for travelling/transporting goods

In addition, we are now witnessing the emergence of new and innovative services and platforms with the potential to further enhance mobility planning and provision. These include the aforementioned platforms, but also concepts such as Mobility-as-a-Service (MaaS). MaaS builds on the concept of multi-modal travel planners with booking and payment functionalities, but taking it a step further by providing a subscription-based model for transport. This is based on the bundle approach already mainstreamed by the telecommunications sector for example. The result may be centralized trading platforms that organize cargo routing and optimize supply chains. These can have an effect on traditional business models, such as the roles of shipowners in maritime transport or truck companies in road transport.

A concept that is related to MaaS is the development of a potentially open source operating system specifically for automated vehicles, including interfaces to information, booking, payments and platform services.

Timely access to operational onboard data via data networks will make it possible to create availability-oriented business models. For example, instead of purchasing or leasing a piece of equipment, future maritime operators may prefer to purchase or lease the availability of the function from an external service provider thereby shifting the responsibility for planning of maintenance from actors located aboard the ship to actors located onshore.[9]

An integration of transport modes can also promote transport systems that are currently not very well developed. For example, Europe's inland waterways can provide a large transport capacity, but currently they are not well represented in the modal split. Assistive and automated support systems could make this transport sector more competitive. Currently, the fact that the majority of ships are old vessels and the prospect of being aboard for two to four weeks does not attract a young workforce to the inland shipping sector. The introduction of assistive and automated support systems in this domain might increase the attractiveness of working conditions in inland shipping. Furthermore, there is a scant likelihood that ships will operate autonomously or unmanned in this sector, particularly due to the technical challenges arising from the need to operate in spatially restricted operating environments.

[9] This concept has been applied successfully in road transport. Michelin Fleet Solutions started to provide availability-oriented tyre services to trucking companies. The business model is focused on the service known as "paying by the mile" rather than on physical components, e.g. the actual number of tyres.

6 ENABLING FACTORS AND THE EXPECTED EFFECTS OF AUTOMATION AND TECHNOLOGY IN TRANSPORT

In this analysis the most relevant trends in each transport mode were reviewed with respect to economic benefit, regulation and governance, technical feasibility, social acceptance, knowledge and skills and labour market dynamics.

- **Economic benefit** encompasses all the benefits that businesses and society can gain from technology minus its opportunity cost. The opportunity cost concerns not just the financial cost, but also what is lost by not choosing other alternatives.
- **Regulation and governance** covers the local and international regulations necessary for the technology to operate in non-confined environments. For such regulations to become operational, policies endorsing such technologies have to be pursued. Generally, social acceptance is a prerequisite for both.
- **Technological readiness** or technical feasibility describes the level of maturity in terms of technology and certification[10]. Novel technologies that are required to implement trends in each cluster are listed in Table 1.2.
- **Social acceptance** describes to what degree the novel technology is approved by society.
- **Knowledge and skills** covers the skills that are required by the future workforce which interacts with novel technologies.
- **Labour market dynamics** addresses the immediate effects of the technology on the labour market.

By assessing selected trends qualitatively with respect to these factors (see Table 1.3), it becomes possible to estimate the "startup curves" for these trends.

6.1 REVIEW OF STATUS OF ENABLING FACTORS FOR AUTONOMOUS OPERATION IN EACH MODE OF TRANSPORT

In collaboration with external experts from the aviation, rail and road transport sectors, WMU reviewed the current status of the enabling factors for a range of key technology categories in each transport mode, with respect to their effect on the future of the current workforce. The results are summarized in Table 1.3.

There are no overarching trends regarding the effects of the enabling factors on the workforce with respect to applications, clusters or transport modes (see Table 1.3). However, when viewing the enabling factors in isolation, three observations deserve mention:

- The factor "economic benefits" may have a negative impact on the workforce in the cluster "maintenance", with regard to rail (vehicles) and road (vehicles and infrastructure) and in the cluster "customer services" with regard to all transport modes.
- The factor "regulation and governance" allows for developments that are likely to have negative effects on the workforce in rail and road traffic management, and in planning and new services in all transport sectors.
- The factor "technical feasibility" enables developments that are most likely to have a negative impact on the workforce in the "maintenance" cluster.

Taking all enabling factors into consideration, the review of the application areas with respect to negative impacts on future work, as outlined in Table 1.3, indicates that:

- Application areas where maturity of the enabling factors is most critical with respect to the current workforce are:
  - Automation of the driving task in road vehicles
  - Automation of the customer interfaces in rail and maritime domains
  - Automation of planning and new services in road transport
- Applications where only a few enabling factors have been implemented are found predominantly in the aviation sector. This is especially the case in next generation air transport services, the automation of aircraft maintenance and the planning of new air services.
- Many applications already are or will become technically feasible in the near future, but other factors are negative. For example:
  - The regulatory framework does not yet allow for implementation
  - Social acceptance is low
  - The economic benefits are low, as in the automated operation of rail infrastructure

A more detailed view on selected applications and regions of the globe is provided in Section 7.3.

[10] For example, at the time of writing, test operations are underway for systems that are technically capable of operating autonomously, but it seems fair to conclude that the safety assurance of autonomous systems is not a mature discipline (McDermid and Daffey, 2018).

Table 1.2 Clusters of trends are enabled by maturing novel technologies

		CLUSTERS OF TRENDS			
	Technology	**Core automation**	**Maintenance**	**Customer interface**	**New services**
	Automatic twistlock systems	X			
	Exo-skeletons	X	X		
	Additive manufacturing ("3D printing")		X		X
Automated vehicles	Gantry cranes	X			
Automated vehicles	Agvs	X			
Automated vehicles	Straddle carriers	X			
	Automatic mooring and docking systems	X	X		
	Battery electric locomotives	X			
	Electric and hybrid propulsion	X			X
Physical robots	Automated collision avoidance	X			X
Physical robots	Physical handling	X	X		
Physical robots	Underwater inspection		X		
Physical robots	Land inspection & repair		X		
Physical robots	Inspection drones (airborne, underwater)		X		
Reliable wireless communication networks	Short range (iec 802.11P, wifi, bluetooth)	X	X	X	X
Reliable wireless communication networks	Medium range (cellular 3G/4G/5G)	X	X		X
Reliable wireless communication networks	Long range (broadband satellite)	X	X		X
	Rfid platforms	X	X		
	Electronic product code (epc)	X	X	X	X
	Internet of things	X	X		
	"V2x connectivity"	X			X
	Sensor networks	X	X		
	Standardization	X	X	X	
	Inter-modal communications networks	X			
Data collection and processing	Data collection	X	X	X	
Data collection and processing	Cloud computing	X			
Data collection and processing	Cross-corporate data shairing	X		X	
Data collection and processing	Data processing / databots	X			X
Data collection and processing	Data mining / big data analysis	X			X
Data collection and processing	Neural networks / "deep learning"	X	X		X
Data collection and processing	Digital back-end it solutions / restful interfaces	X	X	X	X
Data collection and processing	"Digital twin"	X	X		X
Data collection and processing	Artificial intelligence	X	X	X	X
	Reliability and robustness of systems	X	X	X	X
	Blockchain		X	X	X
	Cyber security	X	X	X	X
	Cargo security: fast x-ray	X			
Human-computer interaction	Augmented reality	X	X	X	X
Human-computer interaction	Suitable user interfaces	X	X	X	X
Human-computer interaction	Natural language processing			X	
Human-computer interaction	Pervasive computing	X		X	X

Table 1.3 Status of key technology categories and their effect on the workforce for selected applications across transport sectors

KEY TECHNOLOGY CATEGORIES IN CLUSTERS, BY TRANSPORT MODE	QUALITATIVE JUDGEMENTS: Economic benefits	Regulation and governance	Technical feasibility	Social acceptance	Knowledge and skills	Labour market dynamics
Core automation functionalities						
Infrastructure						
Next generation air transport systems	Positive	Neutral	Positive	Neutral	Positive	Positive
Vessel traffic management	Neutral	Neutral	Neutral	Neutral	Negative	Neutral
Rail traffic management	Neutral	Negative	Negative	Positive	Neutral	Neutral
Road traffic management	Negative	Negative	Neutral	Neutral	Positive	Positive
Vehicles						
Airport automation	Positive	Neutral	Neutral	Neutral	Neutral	Neutral
Ship automation	Neutral	Positive	Neutral	Neutral	Neutral	Positive
Train driving	Negative	Positive	Neutral	Neutral	Positive	Negative
Car/truck driver or operator	Negative	Positive	Neutral	Neutral	Positive	Negative
Automation of maintenance						
Air	Neutral	Neutral	Neutral	Neutral	Positive	Positive
Maritime	Neutral	Neutral	Negative	Neutral	Positive	Neutral
Rail (vehicle)	Negative	Neutral	Negative	Positive	Neutral	Neutral
Rail (infrastructure)	Positive	Neutral	Negative	Positive	Neutral	Neutral
Road (vehicle)	Negative	Negative	Negative	Negative	Neutral	Positive
Road (infrastructure)	Negative	/	Neutral	/	/	Positive
Customer interface						
Air	Negative	Neutral	Positive	Neutral	Positive	Neutral
Maritime	Negative	Neutral	Negative	Neutral	Negative	Negative
Rail	Negative	Negative	Negative	Positive	/	Negative
Road	Neutral	/	/	/	/	Positive
Planning and new services						
Air	Neutral	Neutral	Neutral	Positive	Positive	Positive
Maritime	Neutral	Negative	Neutral	Neutral	/	Neutral
Rail	Positive	Negative	/	Positive	/	Neutral
Road	Negative	Negative	/	/	/	Negative

● Negative effects ● Neutral effects ● Positive effects / Not applicable

Note: The results in this table are presented from the perspective of the current workforceforce. For example, if the economic benefits of technological advances in road traffic management are high, this is likely to have a negative impact on workforce in that sector.

6.2 SCENARIOS FOR START-UP CURVES

The rate of technological adoption is determined by technical feasibility, social boundary conditions (regulation, policy and social acceptance) and economic benefit. Three scenarios are considered in the framework of these dimensions (Table 1.4).

Table 1.4 Three scenarios of technological adoption

SCENARIO	ECONOMIC BENEFIT	TECHNICAL FEASIBILITY	REGULATION AND POLICY
"Do nothing" (no adoption)	Continuation on the current level of technology; no – or very limited – adoption of automation		
"Evolutionary" (slow adoption)	Low	Major technological challenges to be resolved before applications are feasible	In the region where the technology shall be applied, it will be challenging to achieve social and legal acceptance
"Revolutionary" (fast adoption)	High	Applicable technology is already available, or is likely to be available soon	In the region where the technology shall be applied, social and legal acceptance can be achieved

6.2.1 "DO NOTHING" SCENARIO (NO ADOPTION):

In this scenario, the assumption is that a further adoption of automation and technology will be very limited. The effects on the employees are dominated by changes in trade volumes and routes.

6.2.2 "EVOLUTIONARY" SCENARIO (SLOW ADOPTION):

This scenario describes developments, based on the assumption that economic benefits are low and technical and/or legal boundaries are high. For example, it seems fair to conclude that across all transport modes the safety assurance of autonomous systems is not a mature discipline (Jalonen, Tuominen, and Wahlström, 2017; McDermid and Daffey, 2018).

In this situation, the speed of adoption basically depends on the time required to achieve social and legal acceptance for introducing certain types of technologies.

Initially, we will see projects being implemented in areas under national legislation e.g. Yara Birkeland in maritime transport (The Motorship, 2017), or in parts of neighbouring countries on the basis of bilateral legal agreements. If these applications become successful and socially accepted, they may gradually be adopted on a larger geographical scale, for example in trade.

6.2.3 "REVOLUTIONARY" SCENARIO (FAST ADOPTION):

Assuming that the economic benefit is high and the legal boundaries are low, this scenario describes the fastest developments that are considered feasible. The speed of adoption essentially is dominated by the availability of reliable technology that is required to implement technical trends.

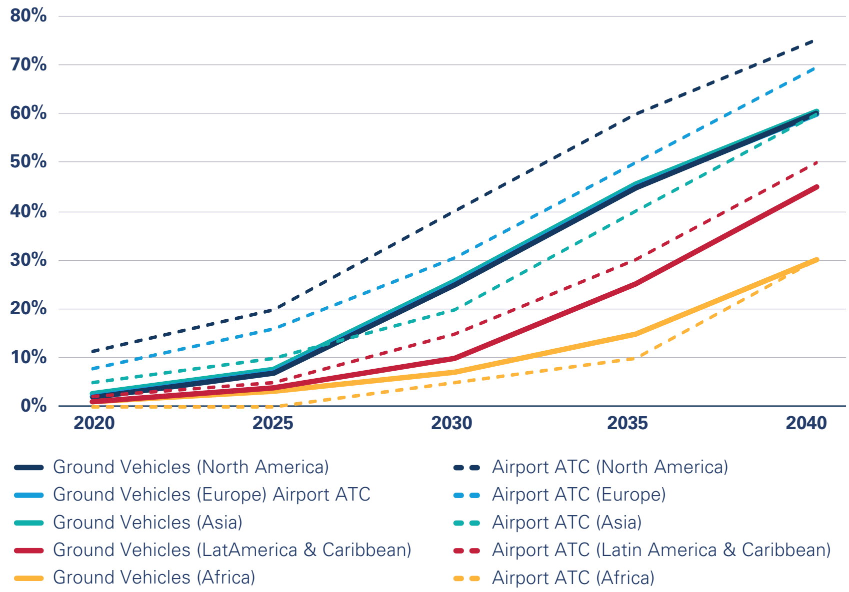
For example, in maritime transport the challenges of creating the required technical infrastructure may quickly be addressed in certain ports, with the aim of being ahead of, or on a par with, the competition. Once the infrastructure is available, the operation of ships with a higher level of automation may become increasingly attractive for operators. Driven by business demands, pressure will be to fill existing gaps in legislation at the national and international levels.

6.3 STARTUP CURVES FOR SELECTED APPLICATIONS OF AUTONOMOUS SYSTEMS IN VEHICLES AND INFRASTRUCTURE OPERATIONS

Aviation

In civil aviation, a high level of automation has already been implemented. The introduction of further technologies and enhanced automation is not expected to have a major effect on flight crews in the short and medium term. In Asia, Europe and North America more than half of ground vehicles that operate in airports (i.e. 50 to 70 per cent) are likely to be replaced by 2040. The adoption of automated systems in Air Traffic Control (ATC) will also be high North America (65 to 85 per cent), followed by Europe (60 to 80 per cent) and Asia (50 to 70 per cent) (see Figure 1.3).

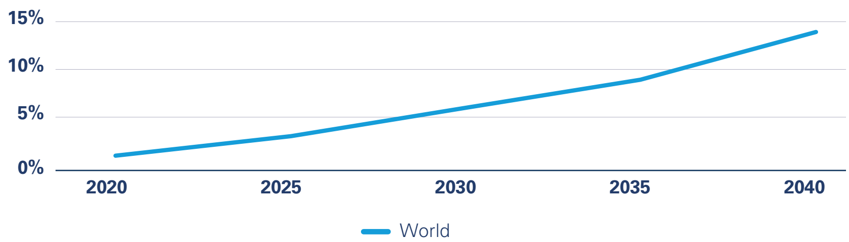
FIGURE 1.3 Startup-curves for selected applications that are related to civil aviation



Maritime transport

In maritime transport, the adoption of novel technologies traditionally happens in incremental steps (see Figure 1.4). The adoption of autonomous ships under human supervision is expected to reach 11 to 17 per cent by 2040, and the expectation is that these ships will be operating in national and regional jurisdictions and specialized trades.

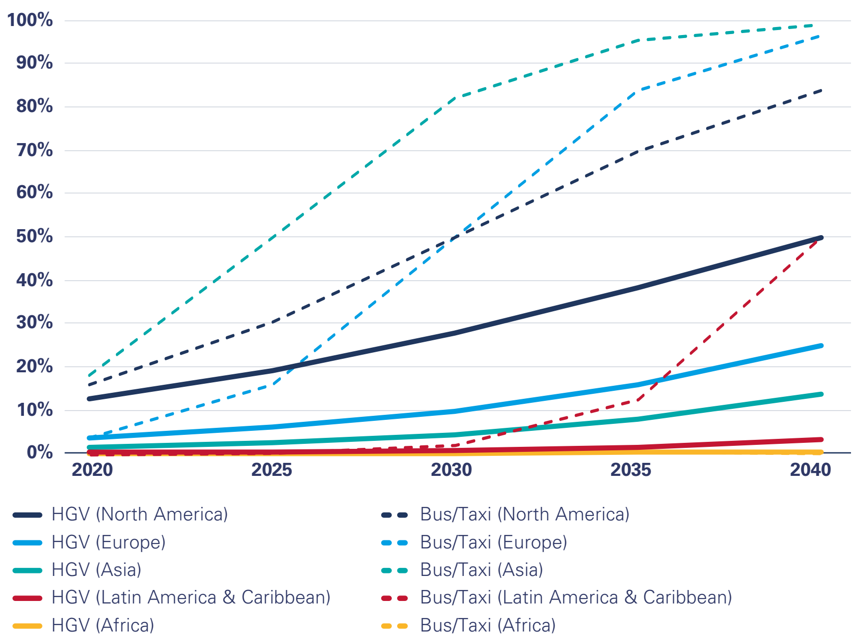
FIGURE 1.4 Startup-curves for autonomous ships with human supervision



Road transport

In road transport, by 2040 buses and taxis are expected to be strongly affected by automation (Asia 90 to 98 per cent, Europe 89 to 97 per cent, North America 76 to 84 per cent, Latin America and the Caribbean 48 to 50 per cent) (see Figure 1.5). Heavy goods vehicles (HGV) will be most affected in North America (42 to 58 per cent), Europe (17 to 33 per cent) and Asia (12 to 16 per cent).

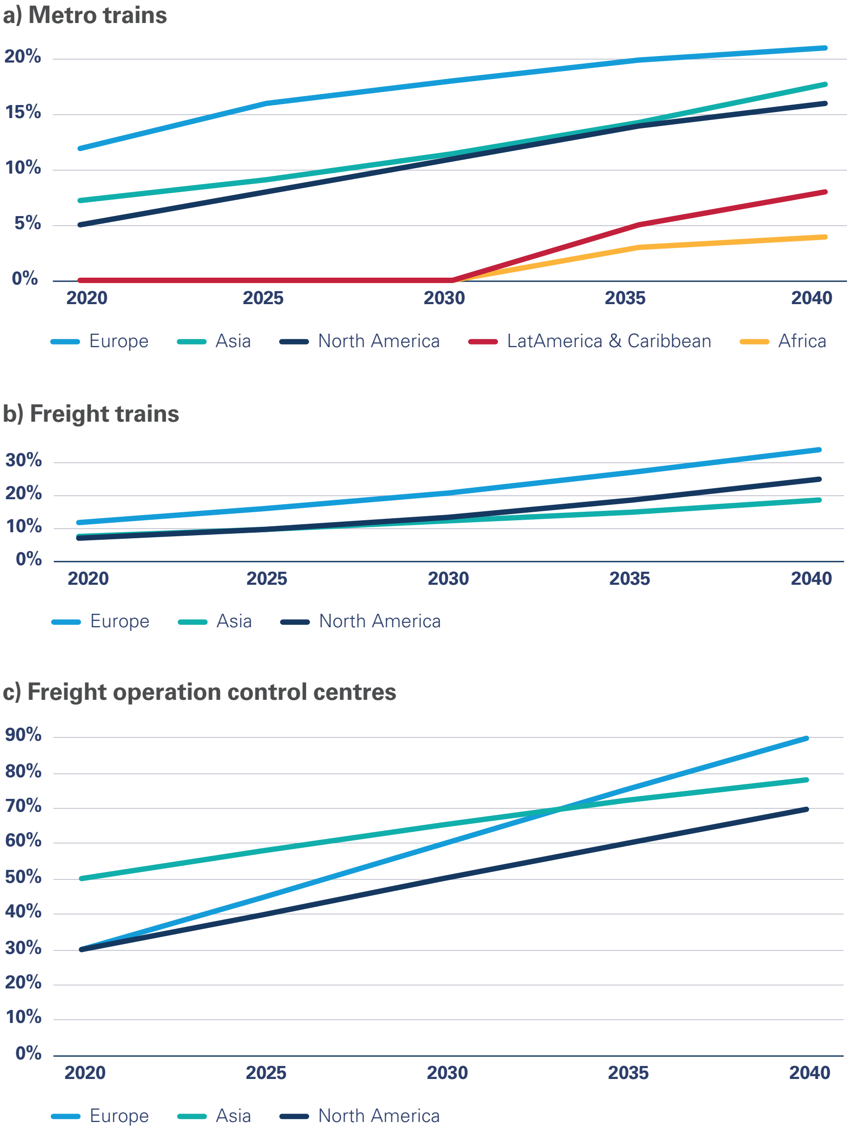
FIGURE 1.5 Startup-curves for selected road transport applications



Rail transport

In rail transport, the adoption rates differ strongly, depending on the type of application (see Figure 1.6). For example, the introduction of fully automated unattended metro vehicles, which are predominantly brought into service on newly built lines, will range from 4 per cent in Africa to 21 per cent in Europe by 2040 (see Figure 1.6a). The adoption of fully automated freight operations has already reached 30 per cent and is projected to increase to between 70-90 per cent in North America, Asia and Europe by 2040.

FIGURE 1.6 Startup-curves for selected train operations



SUMMARY ON STARTUP CURVES

In summary, the startup curves for autonomous vehicle and infrastructure operations indicate that the introduction of automation will be evolutionary rather than revolutionary, but in some trade areas they could be quite extensive. The most affected vehicle operations are taxis, buses, airport ground vehicles in Asia, Europe and North America, heavy goods vehicles in Europe and freight trains in Latin America. Most affected infrastructure operations are airport air traffic control in all regions and freight operation control centres in Asia, Europe and North America.

TRENDS IN TRANSPORT: AIR

MANY TECHNOLOGIES AND AUTOMATION SOLUTIONS HAVE BEEN DEVELOPED TO IMPROVE SYSTEM PERFORMANCE IN TERMS OF SAFETY, SPEED AND SERVICE QUALITY. WITH THE TREND OF AIRPORT PRIVATIZATION AND INCREASED AIRLINE COMPETITION, THE AVIATION INDUSTRY IS GIVING PRIORITY TO EFFICIENCY-IMPROVING AUTOMATION AND TECHNOLOGIES. COORDINATION AND COOPERATION AMONG MULTIPLE STAKEHOLDERS ARE OFTEN NEEDED FOR NEW SYSTEMS TO BE INTRODUCED, ESPECIALLY FOR SAFETY-RELATED OPERATIONS.

AUTOMATION OF CORE FUNCTIONS

Accurate information related to location, weather and sensor reports will be provided to pilots and air traffic control systems in real time. Automated systems can identify safety risks prior to human intervention, leading to better operation decisions on the ground and in the air. Machines can read various travel documents and validate biometric IDs. Combined with artificial intelligence, these systems automate and expedite security checks and immigration.

Air cargo automation, baggage handling systems and automated storage and retrieval systems will be expandable and flexible. Even small airports can afford full system automation. The loading/unloading of cargo and bags, including operations such as Unit Loading

Device staking and cargo build up, will also be automated.

MAINTENANCE OF VEHICLES AND INFRASTRUCTURE

Line maintenance and running repairs of aircraft can be triggered by data collected from thousands of sensors installed in an aircraft. This also enables engineers to scan aircraft systems easily, identifying components in need of replacement or repair.

Suppliers can identify parts nearing the end of their life. Robots can perform certain maintenance functions such as aircraft surface finishing.

Manufacturers can distribute sensitive design and manufacturing data via blockchain securely to 3D printing facilities located in different countries. Aircraft can thus always receive maintenance and repair services in a timely manner.

USER INTERFACES FOR CUSTOMERS AND EQUIPMENT OPERATORS

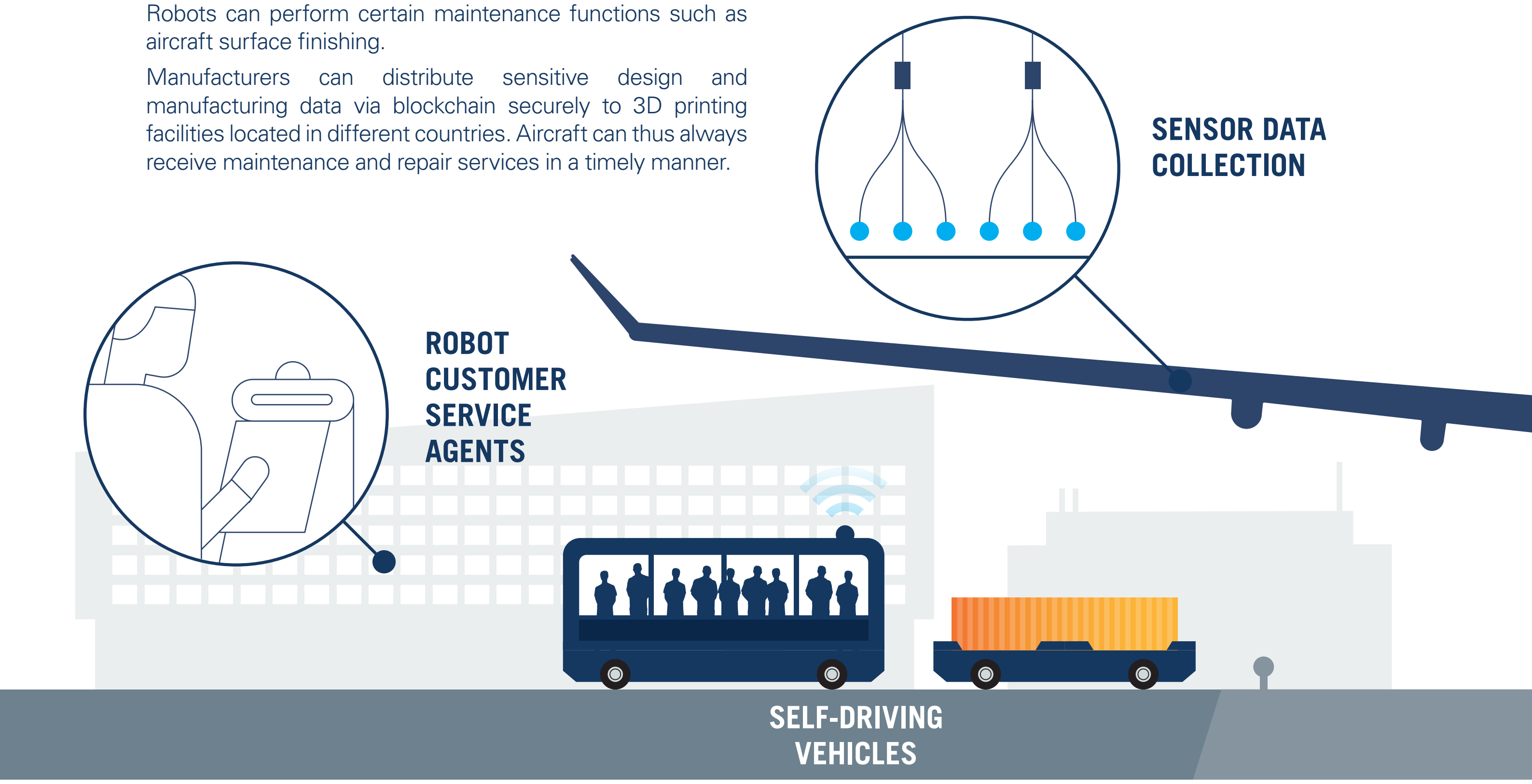
Chatbots help to sell products or answer customer inquiries. AI-backed customer interfaces allow airlines to not only solve specific problems, but also to better understand customers' behaviour, decision processes and preferences.

Robots are increasingly used in customer services, which can speak multiple languages, and provide information related to flight status and weather conditions.

NEW SERVICES

Indoor positioning systems provide passengers with navigation services. They proactively notify boarding time, announcements or other flight details.

Unmanned aircraft systems (drones) deliver products or provide ultra-short-haul commercial flights. They may be used to provide valuable services such as safety checks of aircraft and runways, airport perimeter monitoring and warehouse operations. Aviation automation can help pilots on flight control tasks and in the management of flight missions, or replace certain manual manipulations.



AUTOMATION OF VEHICLES AND INFRASTRUCTURE

Self-driving aircraft-towing vehicles facilitate airport ground operations and handling. Existing **cargo vehicles** and **shuttle buses** may also be replaced with autonomous vehicles.

Next Generation Transportation System **(NextGen)** in the United States aims to improve safety, efficiency and predictability of air transport systems.

The Single European Sky ATM Research **(SESAR)** project aims to improve air traffic management (ATM).

USER INTERFACES

AI and predictive analytics help to keep pace with customer demand and improve operational efficacy, speed and customer satisfaction.

AI also allows airlines to humanize the overall travel experience tailored for individual travellers.

Chatbots are an emerging technology beginning to be able to bring in other forms of AI to help sell products or meet customer service needs.

Japan Airlines, Glasgow Airport and EVA Air have presented their own **robot customer service agents.**

MAINTENANCE OF VEHICLES AND INFRASTRUCTURE

The utilization of **computer-based maintenance programmes** has in some cases reduced the number of scheduled maintenance by 25%.

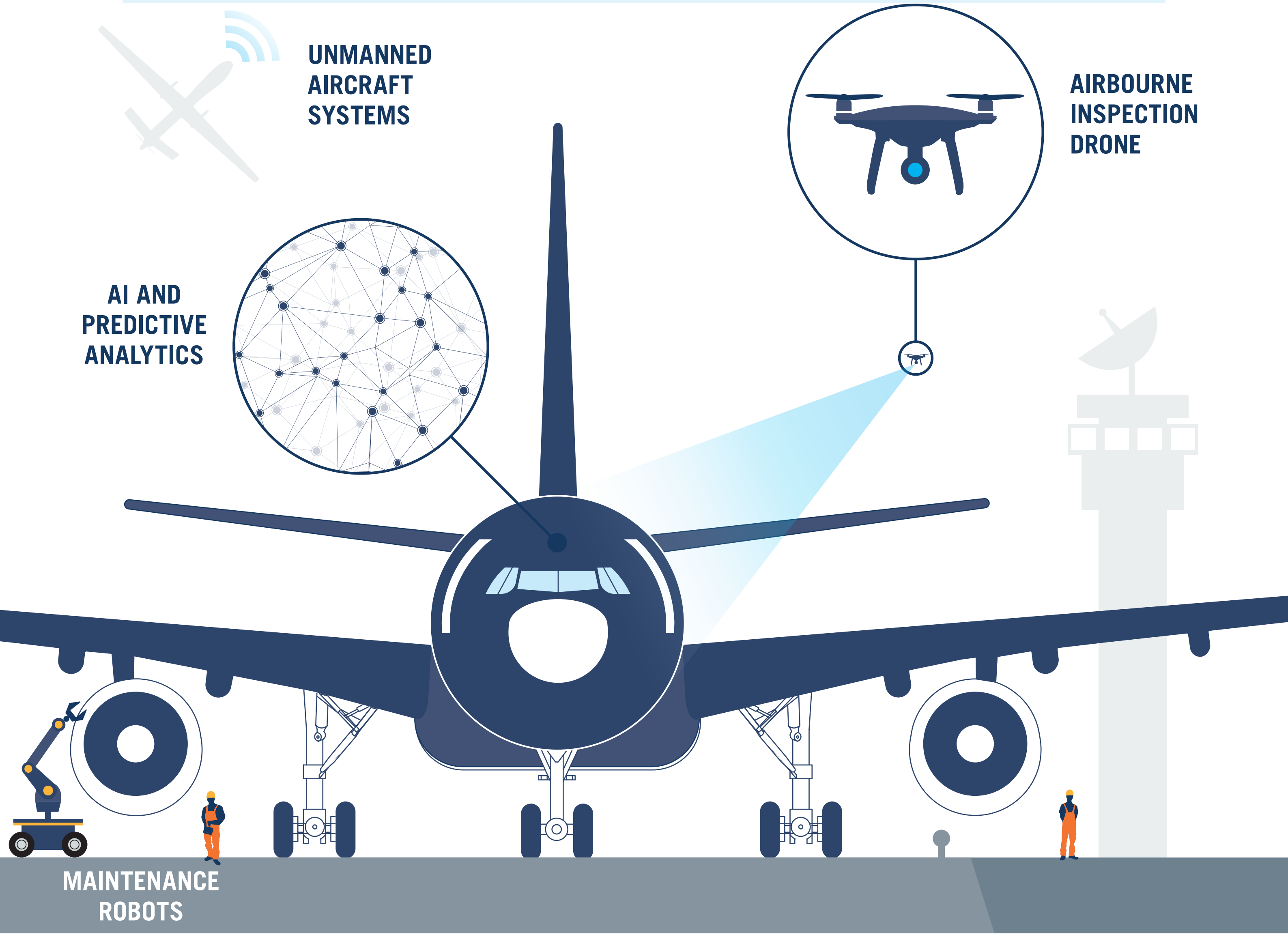
Micro-robots are being developed for inspection and maintenance of hard-to-reach parts such as aircraft engines.

Automated carbon fibre placement machines are being developed to replace manual work and increase operational efficiency.

NEW SERVICES

Facial recognition technology is used to perform customer identity verification and to match passengers to their **luggage through kiosks.**

Companies such as Amazon and Uber have been developing services that utilize **unmanned aircraft systems (UAS) to deliver products or provide ultra-short-haul commercial flights.** UAS can also be useful for the first- and last-mile delivery of small packages, or emergency response to humanitarian crises and natural disasters.



TRENDS IN TRANSPORT: MARITIME

AUTOMATION OF VEHICLES AND INFRASTRUCTURE

Ship crews will be assisted by novel types of technology and automation, ranging from assistive vehicle functions, e.g. track keeping, speed control and fuel saving, to autonomous vehicle operation, with or without human supervision. Control of the transport operations and infrastructure is moving towards centralized and interconnected operation centres, such as fleet operation and maritime vessel traffic service centres.

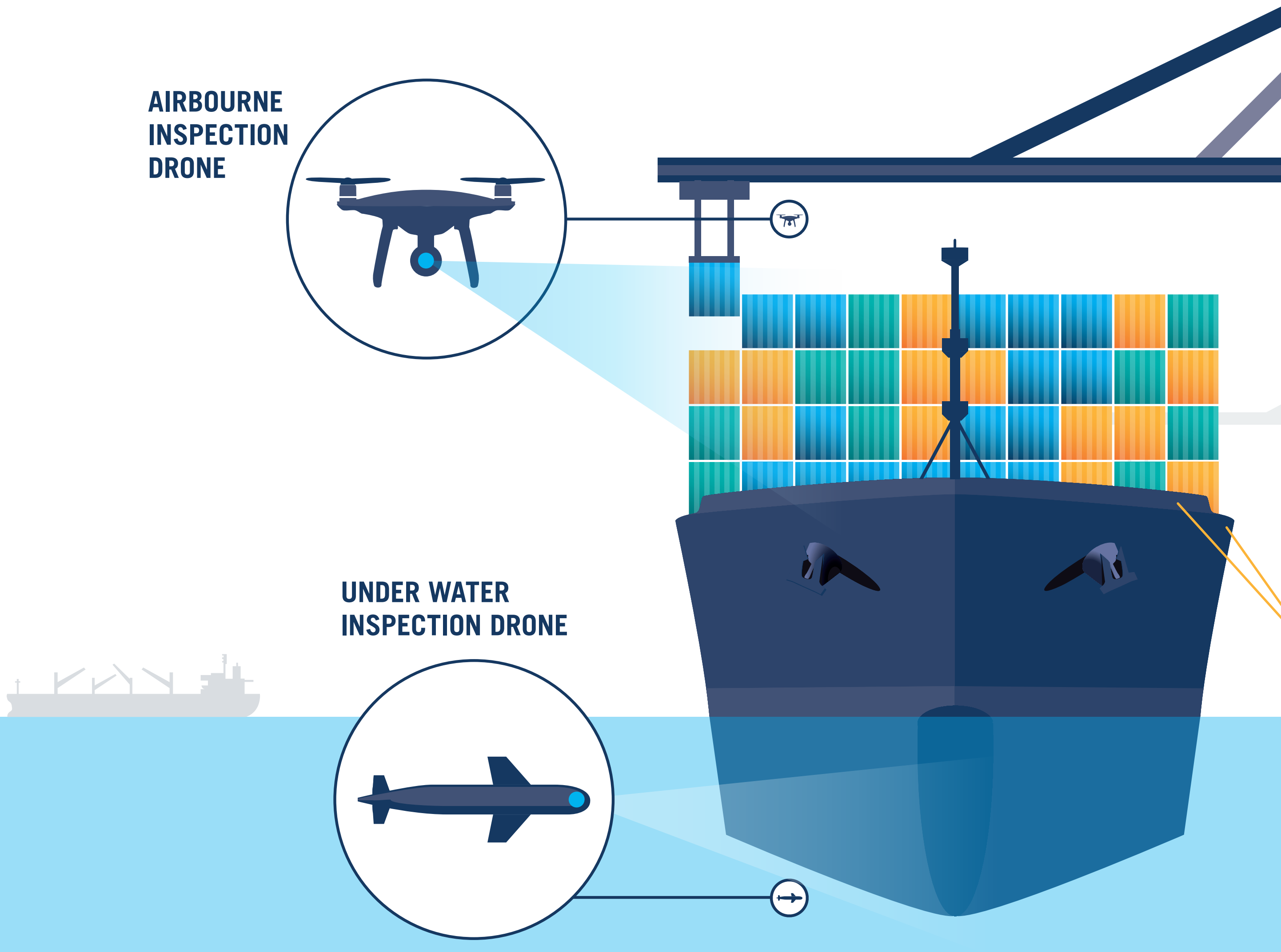
Autonomous ships are most likely to be operated in special trade areas and in restricted regions (inland waterways, national waters and neighbouring countries). Increased support and control will be provided by central operation centres, with experts moving from ship to shore.

MAINTENANCE OF VEHICLES AND INFRASTRUCTURE

Through advances in sensor technology and reliable networks, the condition of equipment aboard vehicles and in the transport infrastructure can be closely monitored. Scheduling maintenance work becomes more flexible, e.g. by specialized personnel located in service hubs who can either perform maintenance work remotely, e.g. assisted by maintenance robots, or be dispatched on demand to where maintenance service is needed. Predictive maintenance will greatly improve the reliability of transport operations by using an array of data, both from vehicles and assets and other sources, such as weather data.

USER INTERFACES FOR CUSTOMERS AND EQUIPMENT OPERATORS

In a world that has an increasing level of collaboration between technical systems and humans, user interfaces need to ensure that the interaction between humans and machines is both safe and effective, and satisfactory for the user. We will see advances in the interaction of technology in applications, such as customer services (e.g. chatbots in booking and ticketing), the control of a wide range of functions in transport vehicles and novel types of maintenance equipment, e.g. servicing robots and drones.



AUTOMATION OF VEHICLES AND INFRASTRUCTURE

Aboard ships, digitalization and automation have already been impacting the work in nautical and engine departments for more than a decade, e.g. unattended machinery spaces and navigational "autopilots". Future evolutionary steps will result in a further reduction of crews onboard and the **provision of remote assistance and operations by specialists located in shore-based service centres.**

The first **fully autonomous ports** have become a reality, but typically are newly built. In the evolution of "traditional" ports, digitalization will improve the safety and efficiency of use of the available port infrastructure.

USER INTERFACES

In customer services, **"intelligent" interfaces,** backed by data mining of interconnected data sources, will make it possible to book customized services.

Digital and physical robots will provide services to customers.

Aboard ships, **human-robot collaboration** will make it possible for crews to perform repair and transport tasks jointly with the support of robots.

Augmented and virtual reality will improve service capabilities and allow for remote service.

MAINTENANCE OF VEHICLES AND INFRASTRUCTURE

Airborne and underwater drone technology make it possible for ship crews to inspect parts of the ship that are hard or hazardous to reach.

Complex engines and other machinery aboard can be **monitored remotely by highly skilled experts on shore.** Maintenance can be planned on demand to minimize the effect on the ship's transport schedule.

NEW SERVICES

The interconnectivity of transport modes makes it possible for current stakeholders and new players to create novel types of services that address demands of customers and transport service providers. New and innovative services and platforms emerge, with the potential to further enhance mobility planning and provision. For example, Mobility as a Service (MaaS) applications for customers and availability-oriented business models for transport providers.

Timely access to operational onboard data via **data networks** will help to create **availability-oriented business models.** Instead of a piece of equipment, an operator will purchase or lease the availability of the function from an external service provider, shifting the responsibility for maintenance planning from ship to shore.

TRENDS IN TRANSPORT: RAIL

AUTOMATION OF VEHICLES AND INFRASTRUCTURE

Automatic traffic management has a long history in railways. Over 70 years of developments towards highly centralized operations control centres has resulted in a high level of automation for signallers and dispatchers. Staff adapted to the daily workload cycle, with only a few operators at night and full staff at peak times. In the future, an even higher level of automation can be expected for conflict detection and resolution.

While the automation of rail traffic is state of the art, the main issue is the automation of the train driving itself. Fully automatic train operations bring both new technical and operational challenges, most of which can be solved by existing technologies, and also legal challenges.

Today the train driver labour market has a lack of train drivers, hence the need to implement automation to reserve the available supply for services where they cannot be replaced in the next decade.

MAINTENANCE OF VEHICLES AND INFRASTRUCTURE

Already today, up-to-date rail traction units like locomotives and passenger trains are typically multiple units. They are equipped with manifold sensors and prepared for condition-based maintenance. The future target is a predictive health monitoring that extends the maintenance cycles on the one hand, and avoids unplanned maintenance and repair as far as possible on the other. Here, automation together with smart data approaches are ongoing trends, which do not necessarily have a significant impact on the workforce.

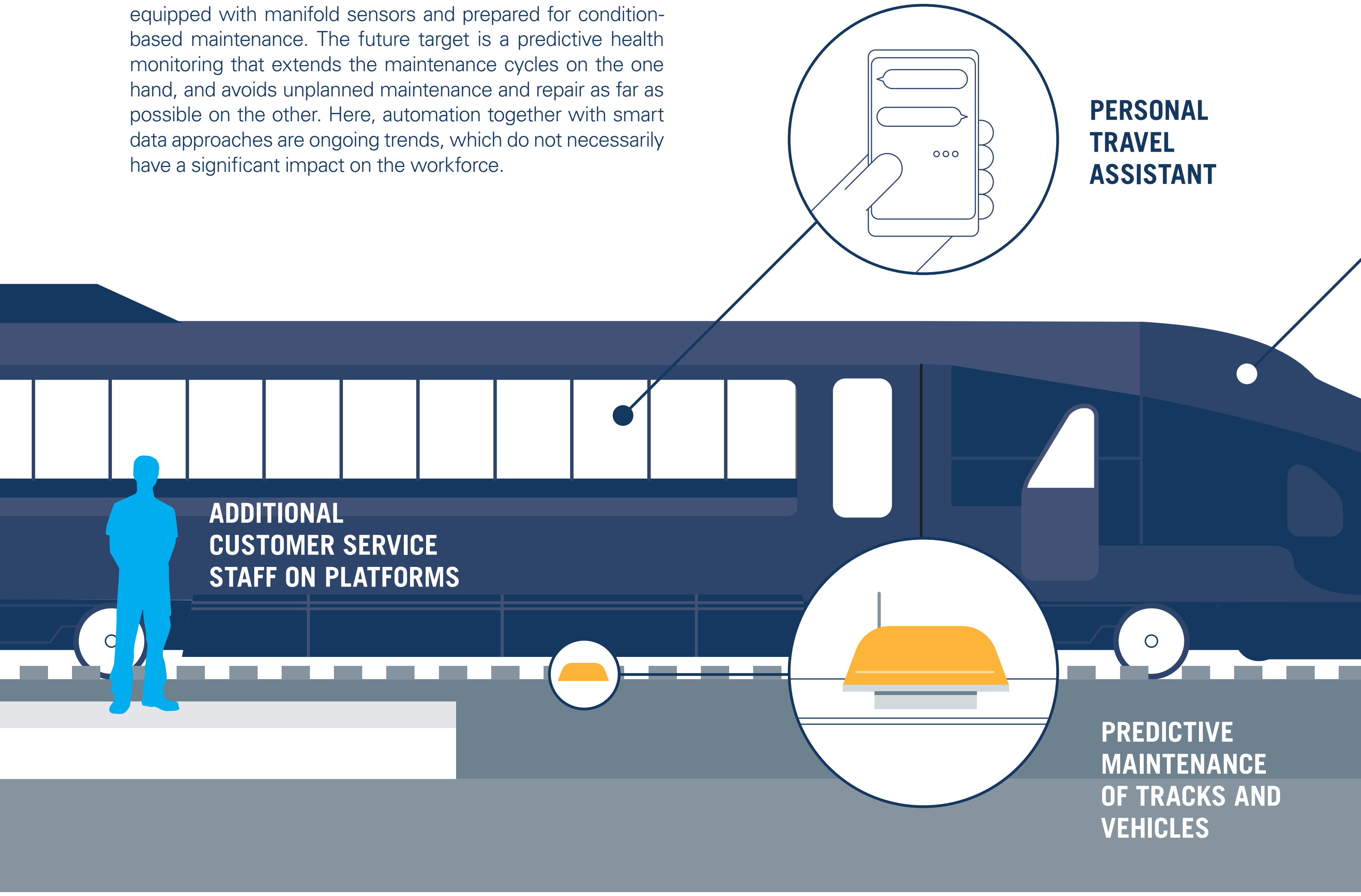
A slow but steady automation process has been ongoing for many years. The focus is mainly on reducing the “d”-tasks (“Dirty, Dangerous and Difficult”) . A full automation is not to be expected in the immediate future. This trend will lead to an evolutionary and rather slow reduction of the workforce, together with an improvement of working conditions.

USER INTERFACES

Individualized information systems, such as Personal Travel Assistant apps, will assist in journey planning, and will provide information on connections and places of interest during travel. Service robots on passenger trains will offer amenities during a journey.

NEW SERVICES

By 2050 passenger mobility will increase by 200-300% and freight activity by up to 150-250% (OECD/ITF, 2017). Smart solutions will need to be implemented to provide adequate transport capacity for the growing volumes of cargo and people. We will see intelligent, more integrated systems for moving passengers and freight, or mobility-as-a-service, with trains on demand on secondary lines.



AUTOMATION OF VEHICLES AND INFRASTRUCTURE

With the advent of **driverless trains,** the labour will shift from drivers to **additional customer service staff on platforms.**

Hybrid or hydrogen trains and locomotives will allow for cleaner and more versatile operations.

USER INTERFACES

New types of interactive information systems will assign passengers a more active role.

Individualized apps for mobile devices will provide a **Personal Travel Assistant** who presents information on connections and supplementary information on the journey.

MAINTENANCE OF VEHICLES AND INFRASTRUCTURE

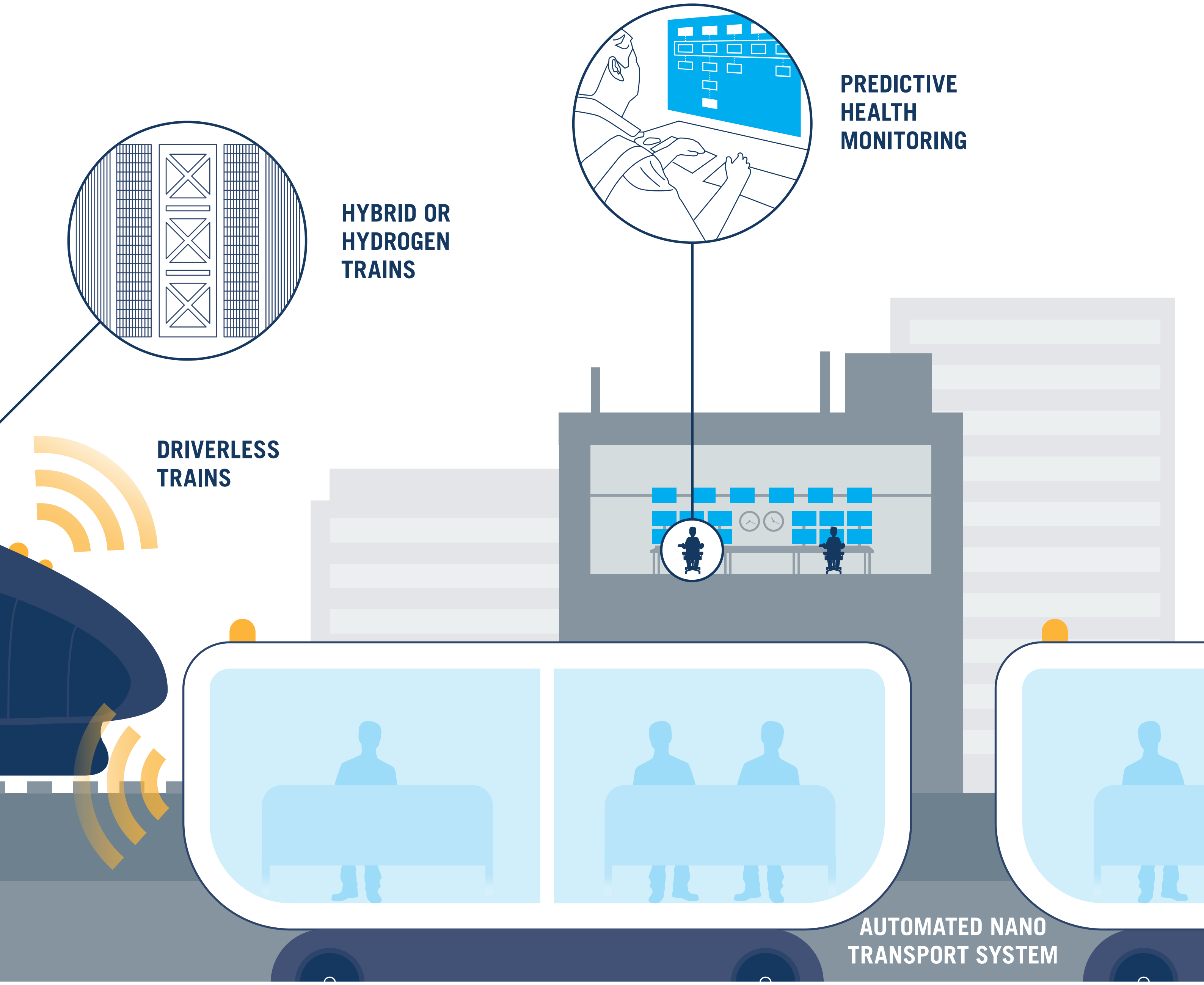
Condition-based and predictive maintenance of tracks and vehicles helps to optimize maintenance tasks and to dispatch maintenance crews.

Predictive health monitoring extends maintenance cycles and avoids unplanned maintenance and repair.

NEW SERVICES

Novel types of trains consist of **independent drive units** that can be combined with almost any kind of functional structures and autonomously find the route to their destination, e.g. the **Automated Nano Transport System (ANTS)** and **Next Generation Train (NGT)** high-speed, regional and cargo high-speed systems.

Automation will allow **for new business models for low demand railway lines.**



TRENDS IN TRANSPORT: ROAD

AUTOMATION OF TRAFFIC MANAGEMENT TASKS

The automation of road-based traffic management relates to two individual areas. First, the automation of the actual traffic management tasks, which will likely lead to further reductions in operator positions, with more and more tasks being carried out by algorithms. Secondly, how automated vehicles will affect current traffic management approaches, and what future developments will be required to ensure safe and efficient operation of mixed traffic fleets of automated vehicles – most likely at different levels of automation – and of manually operated vehicles in the transition period. Here an increase in human labour needs may occur, with more sophisticated roles for highly trained individuals.

AUTOMATION OF VEHICLE AND INFRASTRUCTURE MAINTENANCE

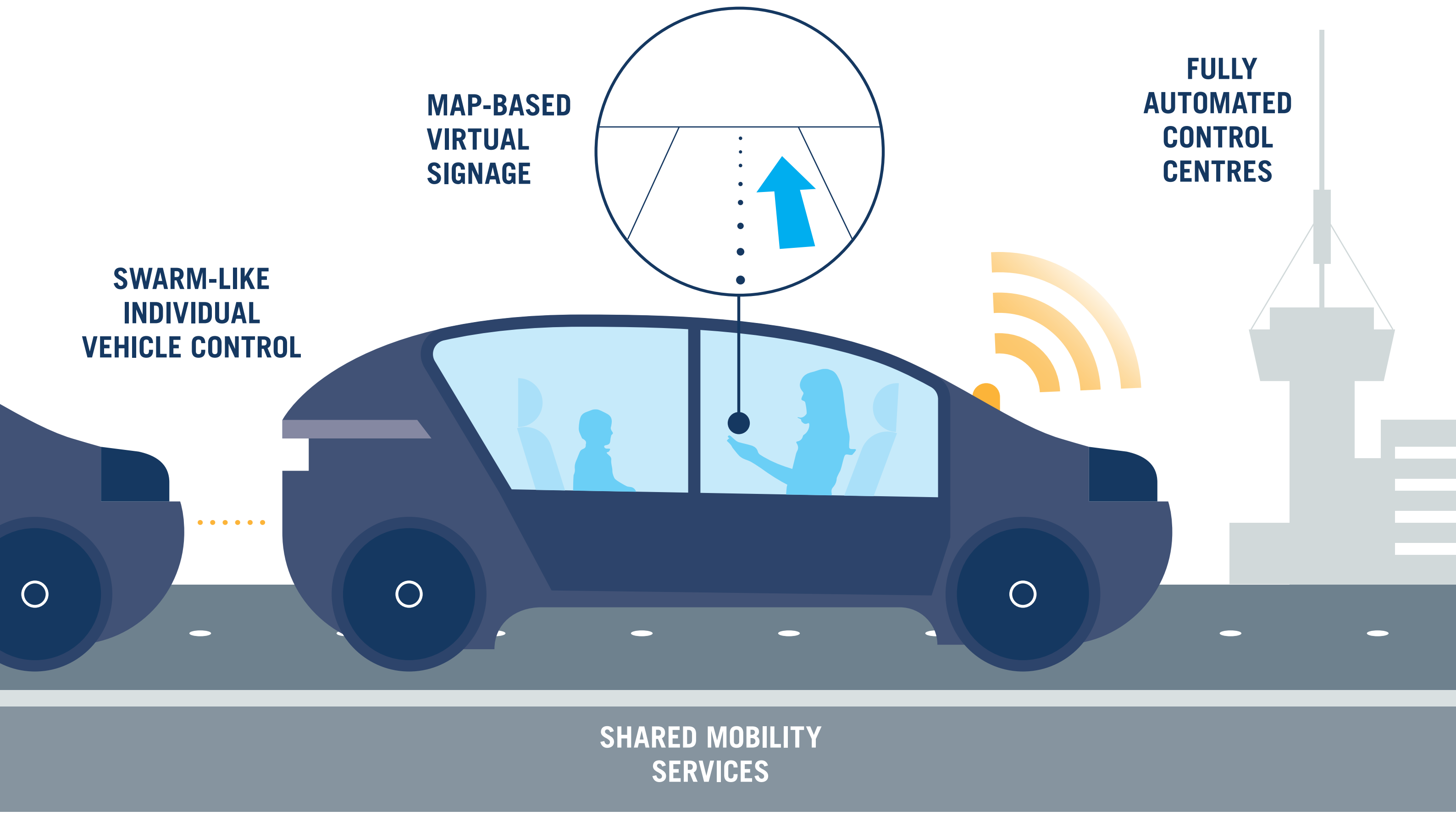
A current key technology trend is the large increase of various types of sensors fitted into modern road vehicles, with more data collected and generated. With the proliferation of data connectivity, both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) or the combination thereof (V2X), a data-abundant environment will be created with a wealth of vehicle-related data. In addition, today a vast number of sensors are embedded into the physical road transport infrastructure, including road surfaces, bridges, and tunnels. Both will enable a predictive maintenance regime, with repair work scheduled in an optimal time-frame.

AUTOMATION OF DRIVER OR OPERATOR TASKS

Many current driving jobs are likely to be impacted by vehicle automation. This includes HGVs and urban delivery vehicle drivers for freight transport and coach, bus, and taxi drivers for public transport. With the promise of efficiency gains, cost reduction and improved road safety, an increase of vehicle automation may occur. The potential of a driver adopting this technology requires further scrutiny. While a negative scenario with a large unemployment of now unneeded drivers seems possible, a more nuanced situation will probably arise. The traditional role of the driver may be transformed into a very different, more highly skilled position. The "vehicle and service agent" will increasingly be removed from driving or even vehicle-monitoring tasks.

AUTOMATION OF USER INTERFACES AND NEW SERVICES

Automation regarding customer interface relates mainly to public passenger transport, but there is a rise of demand-matching and capacity-sharing platforms increasingly in freight transport and logistics. Future developments might bring about increased co-modality, inter-modality and the emergence of new types of vehicles and services, with mixed use of passenger and freight, either shared or at different times. Automation can also impact the planning of transport services generally, including the necessary back-office processes. We are also now witnessing the emergence of innovative services and platforms with the potential to further enhance mobility.



AUTOMATION OF TRAFFIC MANAGEMENT TASKS

Traffic lights and road signs will increasingly disappear, replaced by **individual vehicle control** (e.g. "swarm-behaviour"), a **machine-readable infrastructure** and **map-based virtual signage**. Traditional traffic management centres will be replaced by corridor-, city- or country-wide **integrated and almost fully automated fleet dispatch and control centres,** based on an **Internet-of-Vehicles (IoV)** approach.

AUTOMATION OF VEHICLE AND INFRASTRUCTURE MAINTENANCE

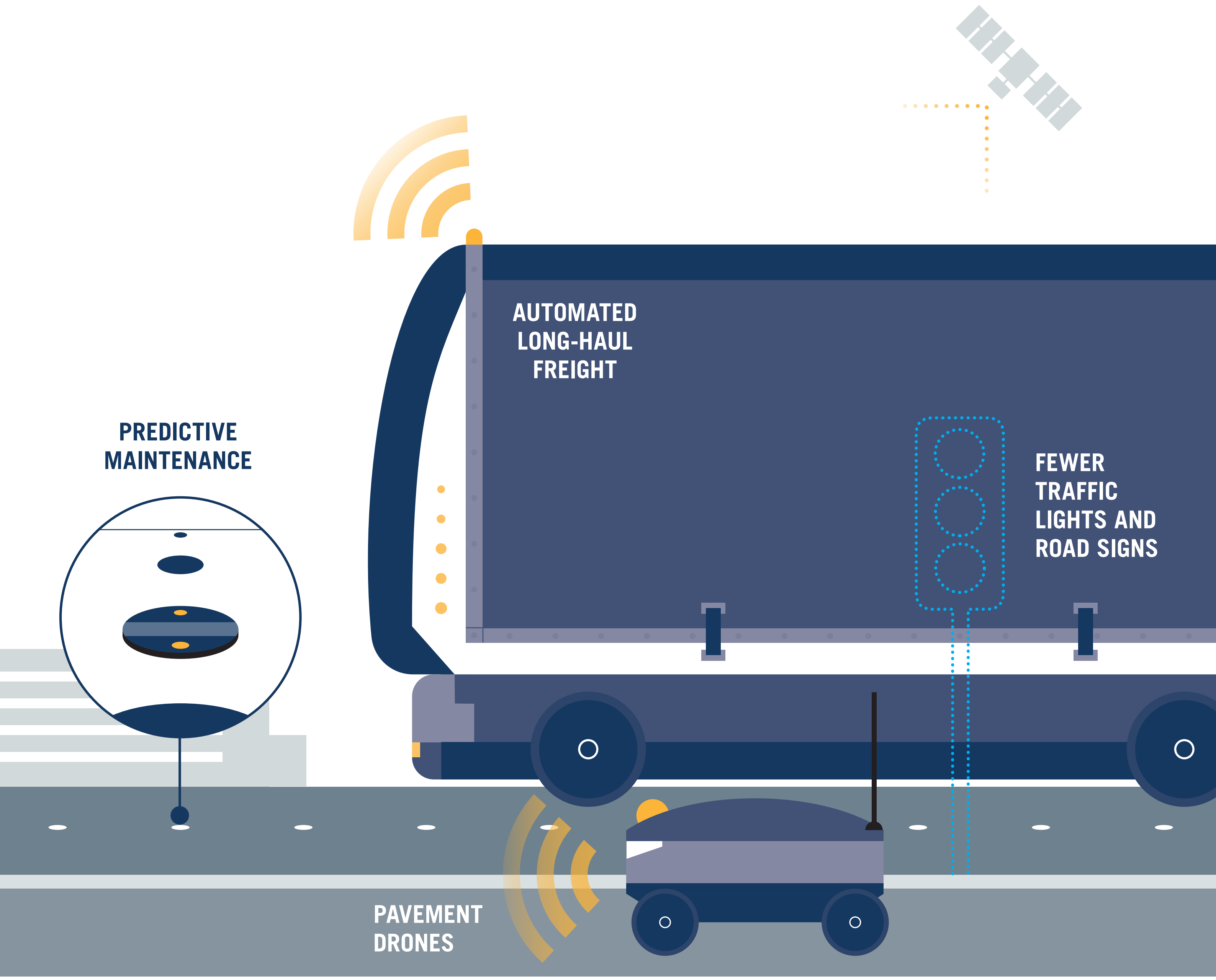
Both maintenance of road vehicles, freight and public transport fleets, and the underlying road infrastructure, both bridges and tunnels, will become entirely predictive without any scheduled work. This will **replace the current regimes by fully, large data-driven and automated mechanisms for on-demand work.**

AUTOMATION OF DRIVER OR OPERATOR TASKS

New services and vehicles will emerge providing innovative mobility solutions for freight and passengers; and often combined in the same vehicle or operating individually in different time periods, based on large-scale utilization of high levels (above SAE level 3) of vehicle automation. This includes **automated long-haul freight vehicles, urban-shared mobility services and pavement drones.**

AUTOMATION OF USER INTERFACES AND NEW SERVICES

Mode-integrated demand-matching platforms for both freight and passenger transport will emerge, together **with user and consumer-centric solutions for information, booking, payments and ticketing,** including subscription models **(MaaS)** for personal mobility. This also includes the use of automated vehicles.



FINAL REMARKS

Chapter 1 focused on the new technology landscape and its far-reaching implications for the global economy and productivity. Today the world is witnessing a Fourth Industrial Revolution that is taking place around technological innovation, such as robotics, the Internet of Things, digitalization, artificial intelligence and automation, which are transforming economies, societies and the way we work. The implications of automation reach across manifold sectors, including workers, transport and economy. This chapter showed, for example, how automation and technological innovation are impacting various transport sectors, although technology's adoption is not occurring at a uniform pace.

In Chapter 2 the report looks at the global transport system and provides forecasts looking to 2040 in aviation, road, rail and maritime transport. The report takes note of the reciprocity that exists between technology and transport. There is a similar linkage between trade and automation. The chapter looks at trends in global trade in the coming years as this affects the pace of introduction of technological innovations.

CHAPTER 2

TRANSPORT FORECAST

2

SUMMARY

This chapter will provide forecasts for the transport sector in the year 2040, including projected volumes for aviation, rail, road and maritime transport. This will be followed by an analysis of global trade and the dynamics of transport patterns based on trends in global population growth and economic development. In addition, taking into account trends in technology and automation, forecasts in modal shifts are conducted for the European Union and the Association of Southeast Asian Nations (ASEAN) in order to shed light on the interaction between technological advancement and regional modal shifts in transport.

The transport forecast resulted in to the following key findings:

1. **The overall transport volume is expected to increase, but at a decreasing rate**
2. **The trends in global trade are leading to a new pattern in transport routes**
3. **Improved productivity is expected due to technological advancements that result in modal shifts at the regional level**

1 INTRODUCTION

Transport plays a vital role in the global economy. It makes economic activities possible and transport is itself a major economic activity (U.S. Department of Transportation, 2017). Besides technological progress and the need for political will, two issues discussed in the previous chapter, the demand for transport is primarily based on economics, Government policies and technological change.

This chapter presents forecasts for transport, bearing in mind that technology and transport impact one another, in other words there is an element of reciprocity. Following the identification of technology trends, an evaluation has been undertaken of developments in global trade and in transport demand.

To assess the consequences of the further introduction of technology and automation, it is therefore important to understand how global trade will develop in the coming years. This applies, in particular, to the trade patterns and modes of transport used for facilitating global trade. The demand for transport is primarily in response to the economic environment and population growth. Historically, there has been a close correlation between growth in gross domestic product (GDP) and transport volume, which means that economic activities and trade are among the main drivers of demand for transport. This relationship is confirmed in this chapter.

This chapter is structured as follows. In Section 2, transport volumes of different transport modes are projected. In Section 3, transport pattern dynamics are presented. Section 4 presents the modal shifts in transport and its origins.

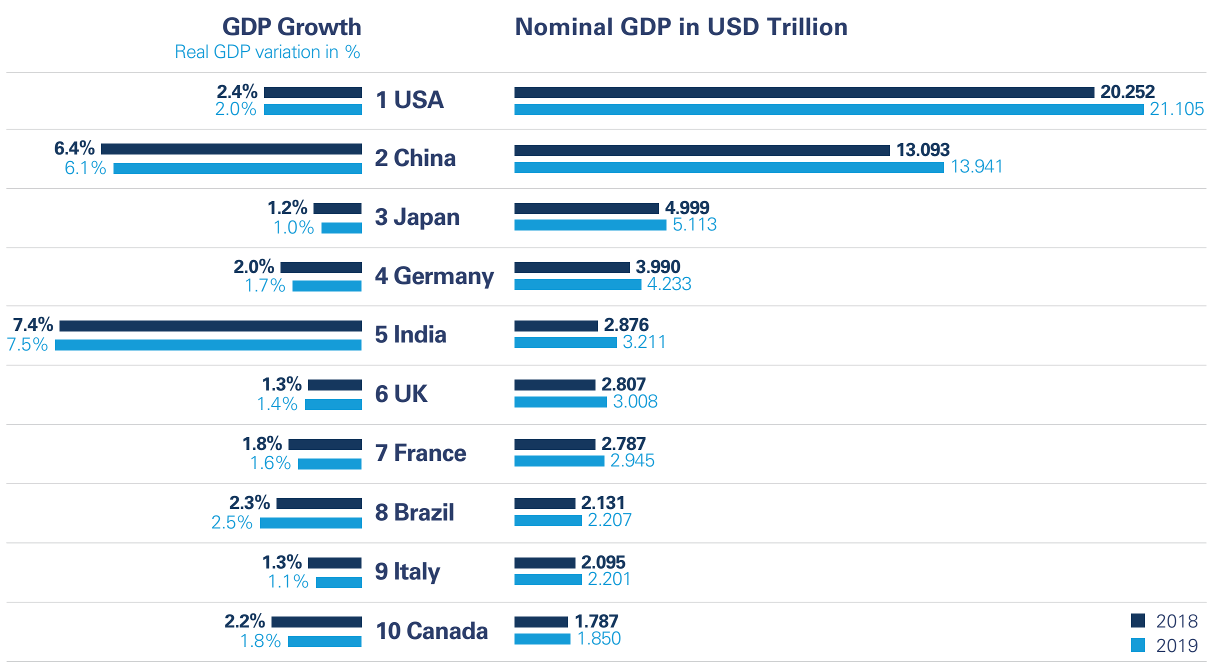
2 INTERACTION BETWEEN THE ECONOMY AND TRANSPORT VOLUME

The demand for transport is primarily in response to the economic environment and population growth. Historically, there is evidence showing that fluctuation and cycle of transport demand derives from the interplay between the demand side volatility triggered by successive waves of globalization and economic development (Stopford, 2009).

INFOBOX 2.A GROSS DOMESTIC PRODUCT

GDP is a monetary measure of the market value of all the final goods and services produced in a period (quarterly or yearly) of time. Nominal GDP estimates are commonly used to determine the economic performance of a whole country or region, and to make international comparisons. Nominal GDP per capita does not, however, reflect differences in the cost of living and the inflation rates of the countries. However, using GDP per capita at purchasing power parity could be more useful when comparing differences in living standards between nations.

FIGURE 2.A Top 10 - The World's Biggest Economies for 2018 and 2019



Source: Focus Economics

Regarding the global GDP growth rate, it slowed to approximately 2 per cent in 2015 and 2016. GDP growth rates are forecast to decrease from 2.2 per cent in 2018 to 1.5 per cent in 2022 (IMF, 2018a). Regarding the global population, overall a higher population results in an increase in the demand for trade. According to projected population figures (United Nations, 2017), the world population is growing at a slower pace than in the past. Nevertheless, estimates place the population at 8.1 to 9.0 billion by 2040.

Regarding volume per category of commodities, it should be noted that as a result of international activities to mitigate climate change, renewable energy in general will be prioritized (DNV GL, 2018). As a consequence, the transport of oil and related products will be reduced after 2030. Between 2030 and 2040, our projection shows that demand for maritime transport is likely to increase at a less rapid pace (see Figure 2.2), which is a result of growth primarily in non-energy commodities. However, a more rapid increase in trade volumes of finished and semi-finished containerisable products is expected to offset the slower growth in oil and related products after 2030.

With respect to the volume per transport mode, the analysis undertaken shows that airfreight transport would increase steadily. Seaborne trade (see Figure 2.6) and road (see Figure 2.5) transport enjoy a relatively high growth rate, but the growth rate itself is decreasing. It is forecast that overall trade, measured as ton-miles, might reach approximately 95,000 ton-miles (see Figure 2.1), and might experience a 2.2 per cent annual growth over the 2015-2030 period and a 0.6 per cent annual growth rate per year after 2030. The growth rate will decrease afterwards until 2040, although growth will still occur. This signifies that an increased demand for transport is expected before 2040.

INFOBOX 2.B TONNE-MILES AND FREIGHT TURNOVER CONVERSION

The concept of tonne-miles to measure freight turnover is basically a physical indicator of transport performance. Freight turnover is the product of a certain quantity of cargo (in tonnes) and the distance of the transport (in kilometres), and it is measured in tonne-km net (in maritime transport it is measured in tonnes-miles, where 1 mile equals 1.852 kilometres). Consequently, transport turnover depends on both the weight of transported cargo and the transported distance. Therefore, freight turnover of different transport modes might need to be converted into a standard unit, i.e. tonne-mile so that turnover of these modes can be compared.

When forecasting transport volume by 2040 as an output, the economic environment reflected in by GDP is used as an input. One should also take note that emerging economies, transition economies and advanced economies are enjoying different rates of macroeconomic development.

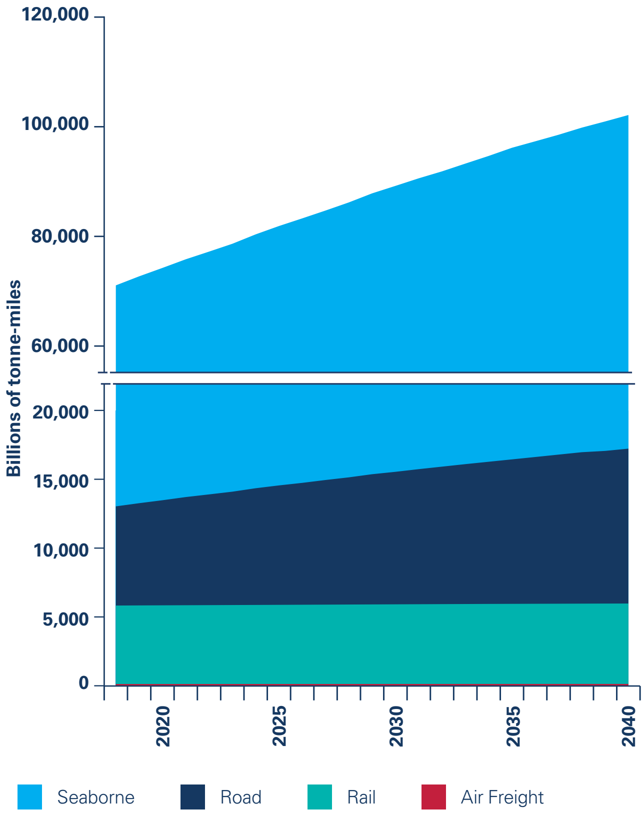
By 2016, eight years after the financial crisis, the global economy was still struggling to attain a durable recovery. The global GDP growth rate reached around 2.4 to 3 per cent in 2016 and 2017 (World Bank, 2018). However, in 2018, maritime transport, the backbone of worldwide trade, supported by the 2017 upswing in the world economy, started to grow at a slightly higher rate, i.e. 4 per cent (UNCTAD, 2018).

As for historical data and projections for GDP, there are mainly three sources: United Nations World Population Prospects, World Bank, and International Monetary Fund (IMF). According to these three organizations, the advanced economies are projected to expand by less than 2 per cent on average by 2022. Supportive macroeconomic policies and continued low commodity prices might lead to a modest recovery in advanced economies. However, this projection assumes that wages and business investment will increase and financial markets will stabilize.

Population is another factor to consider when forecasting transport volume. Higher population results in an increased demand in trade (UNCTAD, 2018).

In this section, the transport volume is analysed for four modes[11]. Within the scope of such volume, in the section on modal shifts, the compatible nature of different models is taken into account to provide an overall projection on the modal shares in 2040. The data used in the models of this Chapter are listed in Appendix B.

FIGURE 2.1 Global transport turnover: projected development to 2040



Sources: World Bank, UNCTAD, International Road Federation, Institute of Shipping Economics and Logistics, DNV GL, WMU analysis and forecast

Note: Air Freight turnover is significantly lower thus not easily visible at the bottom of the graph (125.98 billion tonne-miles in 2018 and 132.75 billion tonne-miles projected to 2040).

[11] However, a set of strong assumptions is necessary to make a projection in transport demand, hence the importance of updating this forecast based on gradually updated parameters, such as trade wars, protectionism, digitalization, among other factors.

2.1 SECTORAL GROWTH RATE

In this section, the report focuses exclusively on freight transport. Passenger transport is not included.

2.1.1 AIR

The air transport industry has undergone rapid change, frequently and comprehensively over the past two decades. This includes new airline entrants, improved aircraft technology and capacity and route expansion. Airbus, one of the world's premier aircraft manufacturers, has long demonstrated outstanding leadership, both by achieving tremendous success in its own right and by sharing forecasts and insights on the future of the aviation industry. According to these reports (Airbus, 2018), a number of trends drive the air transport industry, including global economic trends, population increase, growing individual wealth, disposable income and private consumption.

One trend, based on historical data, shows that global airfreight volumes dropped significantly in 2015, although this downward course was reversed in 2017. Total air freight, measured in freight ton kilometres, expanded by only 2.2 per cent in 2015, less than half the rate of 2014. Sluggish GDP growth and slowing trade volumes, especially in Europe and the Asia-Pacific region, contributed to the slowdown in 2015.

Previous forecasts from the International Air Transport Association (IATA) and the International Civil Aviation Organization (ICAO) had projected an increasing trend for the next five years with annual growth rates between 4.0 per cent and 4.5 per cent. However, the slowdown in 2015 signalled a downside risk for airfreight, which is likely to expand at a much slower pace in the coming years. This reflects the current global economic situation and the trade situation in the short-term.

With regard to the geographical regions, Middle Eastern carriers registered the highest growth rate of airfreight traffic, which reached 11.3 per cent in 2015. Network expansion into emerging markets and supportive local economic conditions suggested a robust growth path for 2016, despite uncertainties stemming from political instability. Airlines from the Asia-Pacific region, which account for 39.7 per cent of world airfreight traffic, expanded moderately by 2.3 per cent. With regard to China, as its economic reforms focused increasingly on services and domestic consumption, decreasing export orders for Chinese manufacturing contributed to a weakening in freight growth in the Asia-Pacific region. Air carriers in Latin America registered an air traffic decline of 6.0 per cent in 2015, which was partially due to the uncertain political situation and deteriorating economic conditions in Brazil.

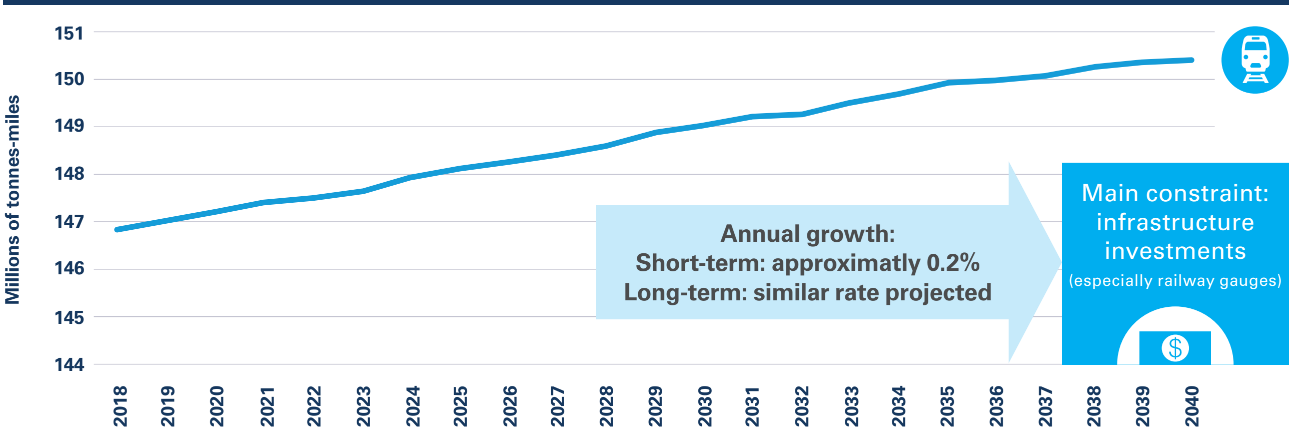
With regard to the overall projection of air freight volume, after the slight downturn identified between 2015 and 2016 (Airbus, 2018), a moderate increase may take place from 2019 to 2040.

2.1.2 RAIL

Many countries and international consulting firms regularly release analytical reports to forecast cargo ton-miles and passenger-mileage. The modal shifts between rail and road are also discussed in the following subsection. According to our projections, rail transport demand will increase very slightly between 2018 and 2040 in the range between 5,700 to 5,860 billion ton-miles.

The trend in rail transport can also be represented in terms of a projected growth rate (see Figure 2.2), which is expected to be almost steady in the future. In addition to the population and policy concerns, the limited capacity of rail infrastructure might be one of the main constraints in an increase in rail freight. If infrastructure investment changes dramatically this would positively impact rail freight volume.

FIGURE 2.2 Forecast in rail freight transport



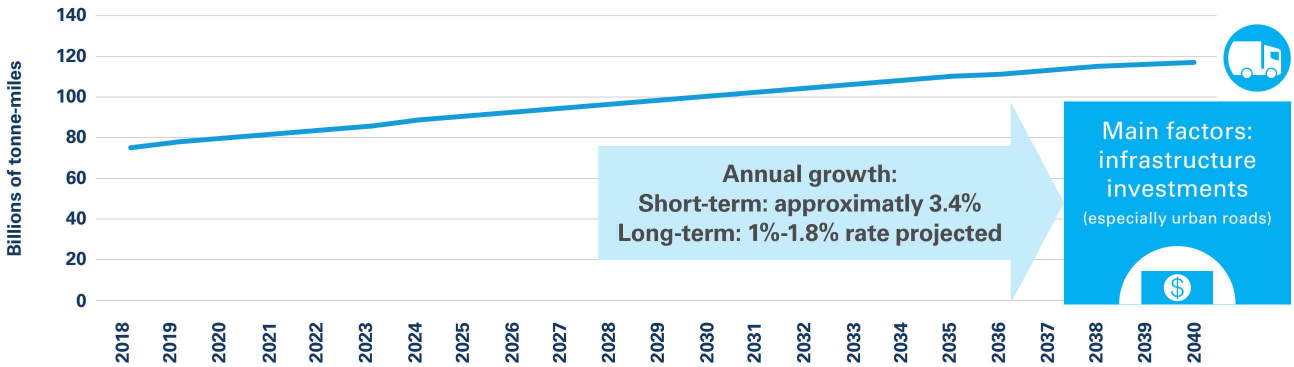
Sources: United States Census Bureau, WMU analysis and forecast

2.1.3 ROAD

This section will focus on road freight. That is because the report has a primary focus on labour employed in the transport industry, and road passenger transport is strongly linked to privately owned cars and a shared riding system with many employees.

In the road freight segment, data sources are more likely to be domestic or regional which means that the analysis will be conducted accordingly. Some reports use traditional time series and Bayesian time series models to make projections for the road sector. On a positive note, the reporting initiative for the road sector will facilitate data-sharing in the near future. Currently, our projection is based on data from the International Road Federation. As indicated in Figure 2.3, road transport will increase in the future at a decreasing rate of growth until 2040.

FIGURE 2.3 Forecast in road transport



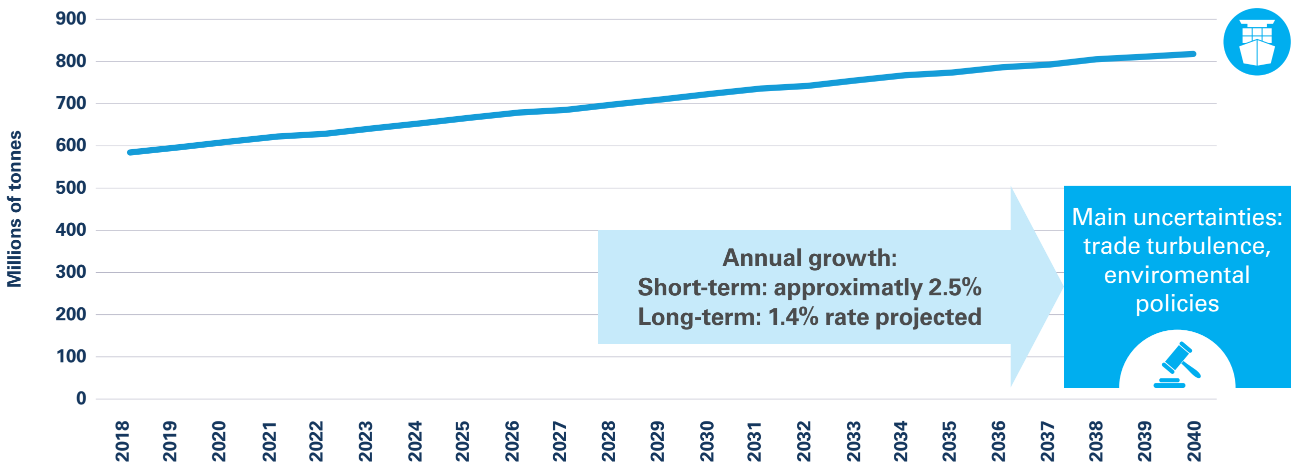
Sources: International Road Federation, WMU analysis and forecast

2.1.4 MARITIME

Seaborne trade and maritime transport remain the principal transport mode and the only solution for the long-distance trade of low value goods (UNCTAD, 2018).

According to our projection, based on the above-mentioned data sources, world seaborne trade will reach 60,000 billion ton-miles by 2020, 74,000 billion ton-miles by 2030 and approximately 84,500 billion ton-miles by 2040. World seaborne trade grew by 2.1 per cent in 2015 (UNCTAD, 2016), which is noticeably less than in previous years. Seaborne trade expanded by 2.9 per cent, when measured in ton-miles, which provides a better insight on the demand for shipping services. Based on our projection, the growth rate in the global seaborne trade shown in Figure 2.4.

FIGURE 2.4 Forecast in maritime transport



Sources: UNCTAD, Institute of Shipping Economics and Logistics, DNV GL, WMU analysis and forecast

This section has dealt with trends in seaborne trade and the road sector, which show that they would contribute more to the overall growth rate of world transport than air and rail transport that would have moderate growth rates. To summarize, overall transport volumes are project to grow by 2040, but at a slower rate.

3 DYNAMICS OF TRADE AND TRANSPORT PATTERNS

3.1 CURRENT TOP EXPORTING AND IMPORTING COUNTRIES

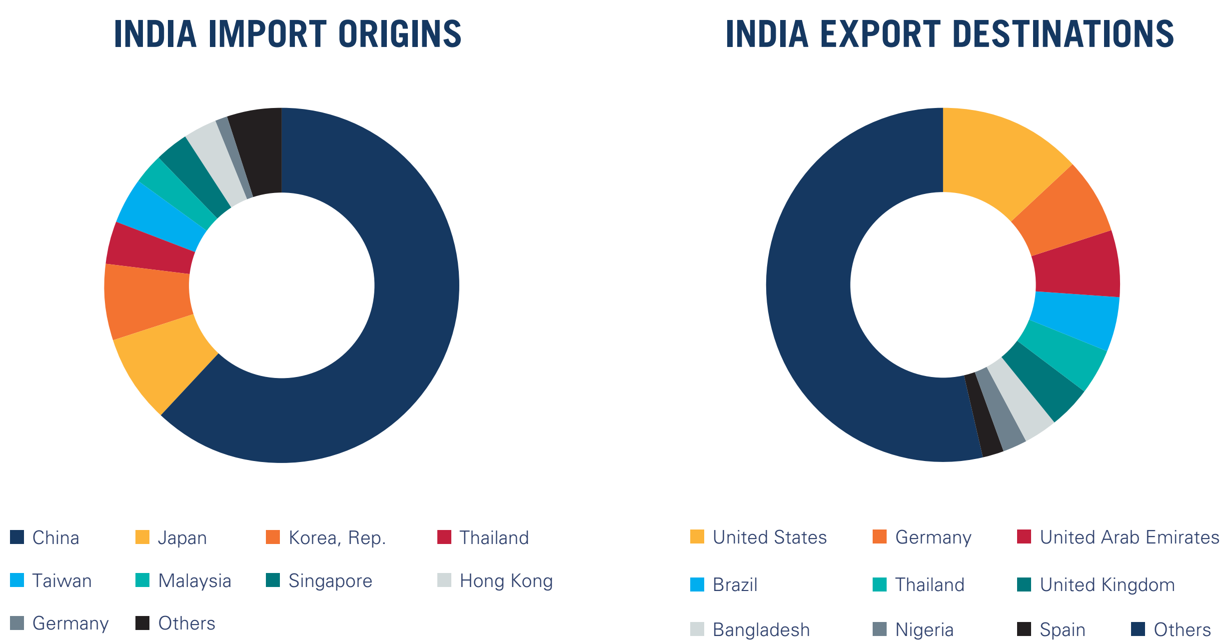
Transport derives from trade and therefore its routes are mainly associated with trade patterns. Imports and exports are always correlated in the context of international trade. World trade has slowed down not only in absolute terms, but also in relation to GDP. In the two decades preceding the financial crisis of 2008, world trade expanded rapidly and outpaced GDP growth. Trade has continued to grow more rapidly than GDP since 2008-2009, but the relationship between them has weakened (OECD/ITF, 2017). The growth rate of world trade remains weak and the year 2017 marks the sixth consecutive year where the growth in volume of global trade was below 3 per cent.

The low growth rates in global trade in recent years can be attributed to moderate export growth from the advanced economies, and in particular to weak demand in these economies and correspondingly slower growth of exports from emerging economies. In advanced economies, imports expanded by 4.5 per cent in 2015, whereas developing and emerging economies were marked by stagnation. Exports are following a similar path. Trade is expected to accelerate slowly, reaching a 3.6 per cent rise after 2017. Global GDP is expected to grow by more than 3.0 per cent over the 2018-2023 period (IMF, 2018a), and merchandise trade volumes are set to rise by 4.4 per cent in 2018 and 4 per cent in 2019 (WTO, 2018).

In addition to focusing on global trade and the absolute global volume of imports and exports, the report also focused on one sample country, India, with its relatively high annual growth rates in transport demand. Sample countries highlighted in this section were chosen mainly because of the availability of data.

Growth in the transport sector is projected to increase in the Indian and Pacific Oceans, with an increase in seaborne transport likely to be focused in the Asia and the Indian Ocean regions (see Figure 2.5), thereby highlighting the importance of Asian trade. Thus a slow eastward shift, in line with the growth of Asia's share in the pattern of transport routes, will occur.

FIGURE 2.5 India and its export and import trade partners (2017)



Sources: IHS Markit, WMU analysis and forecast

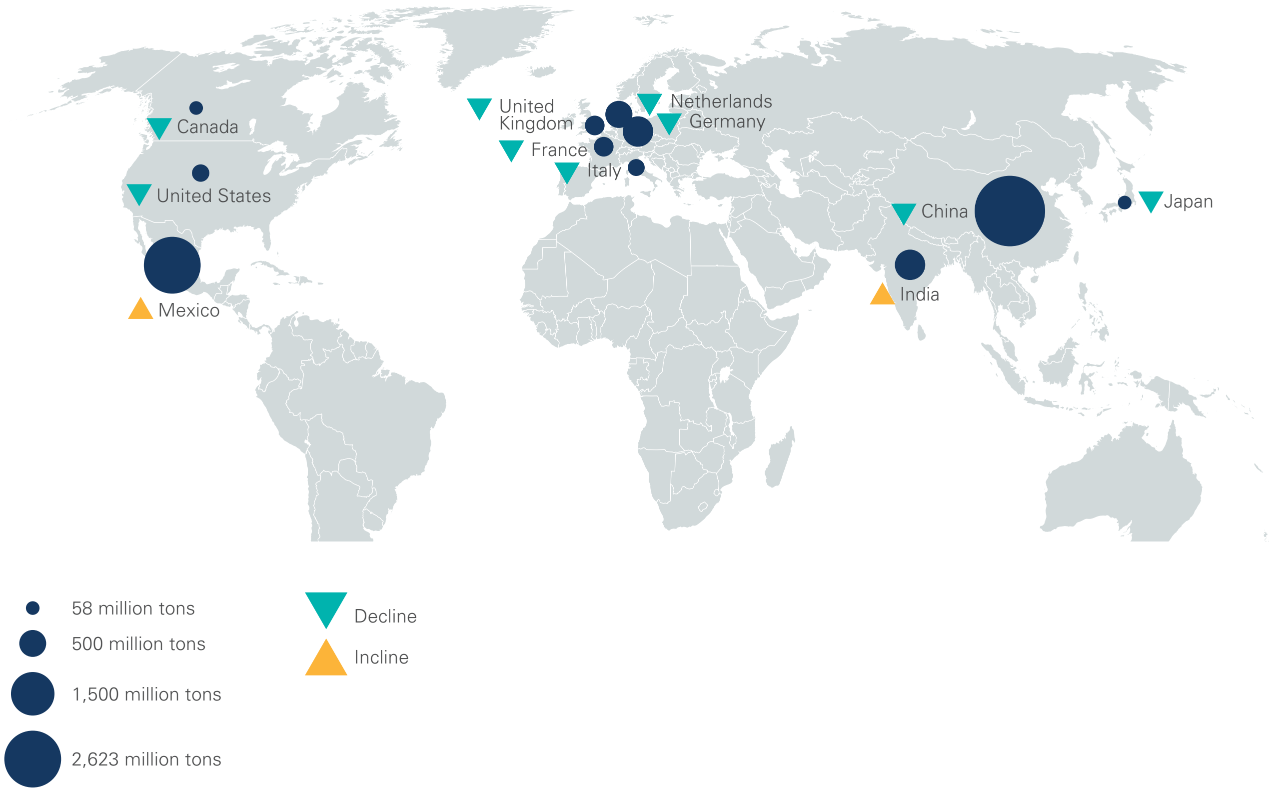
In short, a new pattern of trade and transport routes will emerge, which means that the emerging transport service connection will take place in the trade zones where imports and exports register an increase in volume.

3.2 FUTURE DYNAMICS IN TRADE OF SELECTED COUNTRIES

Turning to transport routes and the countries located along these routes, in coming years differences will emerge in the growth rate statistics. One important factor to be taken into account is that the growth rate in China may decrease with time. It is also to be noted that growth rates for many of the developed countries may differ. France and Germany, for example, might experience a decline of imports and exports in terms of volume in the future, while others, like the United States, might experience a growth in transport volume for its exports and a decline in transport volume for its imports by 2040.

Transport demand of emerging economies, such as those of Mexico and India, may enjoy higher growth rates since trends in transport follow trading patterns. Consequently, new transport routes would emerge because they are linking up with geographical trade zones of emerging economies. According to the projections made in section 2 of this chapter, maritime transport will remain the dominant mode of transport for global trade, with deep-sea cargo-carrying vessels dominating transport services. Currently, 80 per cent of vessel traffic is deployed in the northern hemisphere serving the West-East trade routes which coincides with patterns in transport.

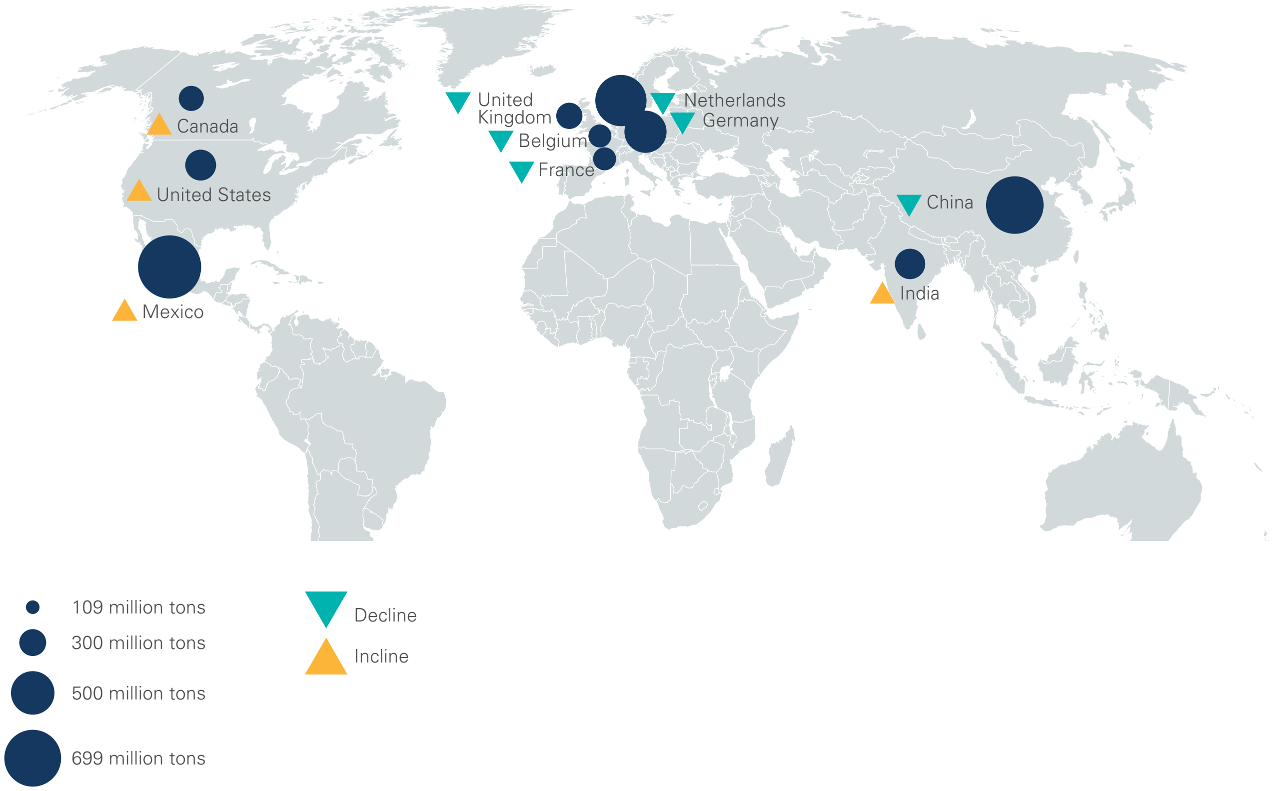
FIGURE 2.6 Trends of selected countries (2017-2040): imports



Sources: IHS Markit, WMU analysis and forecast

Based on our projection, some sample countries with importing and exporting economies are presented below with their trade volume figures for 2017 and their forecast in projected trends to 2040. Based on the projections made, Figure 2.6 presents forecasts of imports by volume for these sample countries, marked with either a red or a green arrow respectively. China's volume of imports might slow down and decrease in the long run. Most developed countries, for example France and Germany, will register an almost similar slight decline, while the United States will see a drop in imports by 2040. As a transition economy, Mexico might enjoy a higher import growth rate compared to advanced economies.

FIGURE 2.7 Trends of sample countries (2017-2040): exports



Sources: IHS Markit, WMU analysis and forecast

As indicated in Figure 2.7, the trends in export of these sample countries change through 2017 to 2040. The investigation on the imports of these sample countries shows that their dynamics are regarded as leading to new patterns of transport and trade routes. For example, U.S. imports by volume show a decreasing trend while its exports indicate an increasing pattern. Mexico registers an increasing trend for both exports and imports, which implies that in this intraregional area, the transport patterns would change to accord with shifts in exports and imports by 2040.

However, it should be noted that the timeline of 2030 is significant and deserves further attention because energy consumption, for example crude oil, is expected to change significantly after 2030 due to expected changes in energy policies (DNV GL, 2018), in line with the Paris Agreement and the progressive implementiion of the UN Sustanaible Development Goals.

In addition to the energy policy factor, other reasons that would promote such a dynamic trade pattern would be growth in the global economy and in population figures, as mentioned in Section 1 of this chapter.

Moreover, by comparing volume, value and growth rates, one can note that ships and vehicles may visit regions more frequently where the transport volume is increasing. By identifying the top 10 countries by import and export value, it can be inferred that these countries are either experiencing a fast pace of economic growth, or they are operating in an advanced technical environment with high living standards, which means people are less willing to pursue seafaring as an occupation.

4 INTERACTION BETWEEN TECHNOLOGY AND REGIONAL MODAL SHIFTS

Sections 2 and Section 3 of this chapter focused on the global level. In this section, we turn our attention to the regional level. An important concern raised by practitioners is that, to some extent, maritime transport may be replaced by other transport modes at certain points in time and in some regions. However, based on the analysis made in Section 2 and Section 3, long-distance maritime transport will remain the leading mode in terms of the scale and volume of goods carried.

4.1 MODAL SHIFT IN THE EUROPEAN UNION

A substitution among various transport modes is defined as a modal shift. Further reports released by organizations such as the European Conference of Ministers of Transport and OECD, indicate that market shares of rail, road and short sea shipping were constantly changing in the past three decades. In particular, inland waterways and rail market shares have clearly fallen over the years. Competition between rail and road transport has also been seen in the market. Factors affecting modal shifts are stressed in many reports, including cost reduction and increments in productivity.

INFOBOX 2.C MODAL SHIFTS

At the regional level, each mode of transport serves its niche market. A modal split stands for the market share of a specific mode of transport. The modal split for freight transport varies greatly by region, and is largely determined by geographical and economic factors.

The term **modal shift** stands for a dynamic situation where some freight chooses to use one transport mode over the current mode it uses. Consequently, shares of each transport mode changes, and such dynamics are identified as a modal shift. In other words, it is a service substitution between transport modes.

When it comes to modal shifts, the enabling factor of shifting freight from one choice of transport mode to another could be the cost of related transport service and transport time spent accordingly. In that regard, the transport time spent reflects the productivity level of the related transport mode, the consequence of the transport technology used, among other factors.

INFOBOX 2.D PRODUCTIVITY

Productivity is a measurement of economic performance that equals the ratio between the total output to the inputs used in the production process (U.S. Department of Transportation, 2017).

According to productivity, inputs may include capital, labour, energy, and materials and purchased services. The U.S. Department of Transportation (2017 states that in 2015, labour costs amounted to 27.0 per cent of the total cost in waterborne transport, 26.0 per cent in aviation, 28.7 per cent in rail transport and 27.0 per cent in road transport in the U.S. Although it is not a global percentage, it still points to the fact that the total cost of a specific transport mode will change according to labour cost dynamics.

In addition, productivity may increase for several reasons. For example, new technology or training classes may help workers produce more goods or provide more services in the same amount of time, or with the same amount of resources (U.S. Department of Transportation, 2017). Similarly, policy changes may allow firms, i.e. transport service providers, to operate more efficiently.

Different costs, productivity and efficiency lead to modal shifts at different levels. At the global level, comparisons among long-haul maritime transport, aviation and rail do not normally lead to clearly distinguished pie charts of modal shares. This is due to the fact that maritime shipping service continues to meet most of the transport demand derived from international trade. In addition to the above-mentioned dominance of maritime shipping, another very important related concern from transport practitioners is whether the international maritime shipping service is to be replaced, to some extent, by the other modes. However, based on the analysis made in this report, this is an unlikely scenario.

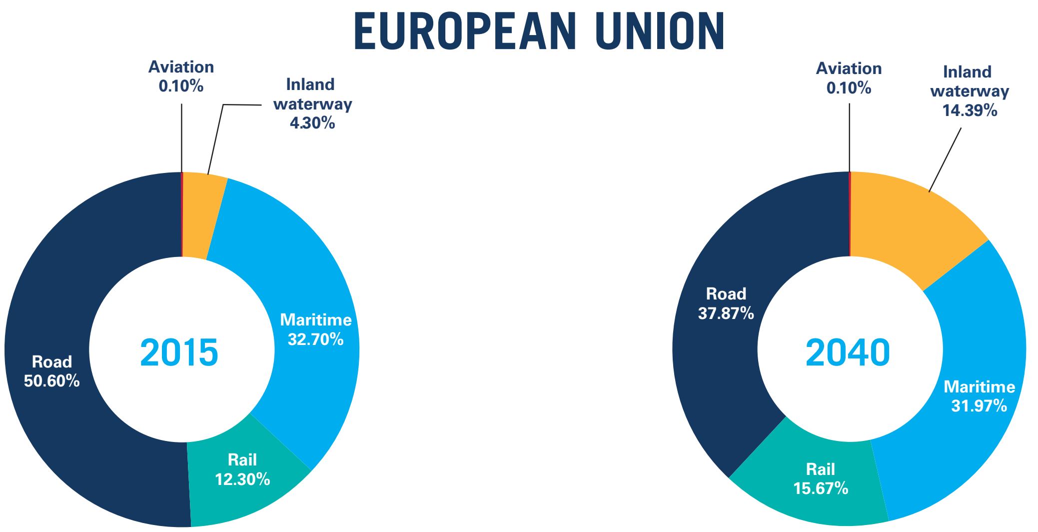
However, at the regional, or EU level, it would be more explanatory if inland waterways are used as an example of waterborne transport and compared with aviation, rail and road, especially as the first autonomous ships will be introduced in inland waterways and not in the deep sea.

Below is an example of modal shares of these three modes within the territory of the EU 28 countries, which considered aggregated data from 2005-2015. From 2010 to 2015 (see Figure 2.10), the shares of these three modes changed slightly, but this period saw a recovery in the share of rail transport.

Based on the historical data in ECMT (2007), the shares of different transport modes changed significantly in the past three decades, as a combined result of infrastructure investment, productivity gained from technology and environmental friendly policies. In short, a very clear trend shows that these four modes are substituting each other in different degrees.

Furthermore, as shown in Figure 2.8, the percentage share of inland waterways transport together with rail transport is forecasted to increase as a result of the development of technology, emission control policies and renewable energy policies. For example, by 2040, the inland waterways transport is expected to increase to 14.4 per cent in 2040, compared to 4.3 per cent in 2015. For its part, rail transport is expected to increase to 15.7 per cent in 2040, compared to 12.3 per cent in 2015. Conversely, road transport will decrease because road transport services are being displaced by inland waterways services and rail transport. However, such trends must be seen in a regional context and will need to be examined further.

FIGURE 2.8 Modal shifts in the EU (2015 and 2040)



Sources: Eurostat, WMU analysis and forecast
Notes: Figures relate to freight only. Computations based on tonne-miles. Aviation and maritime cover only intra-European movements of goods.

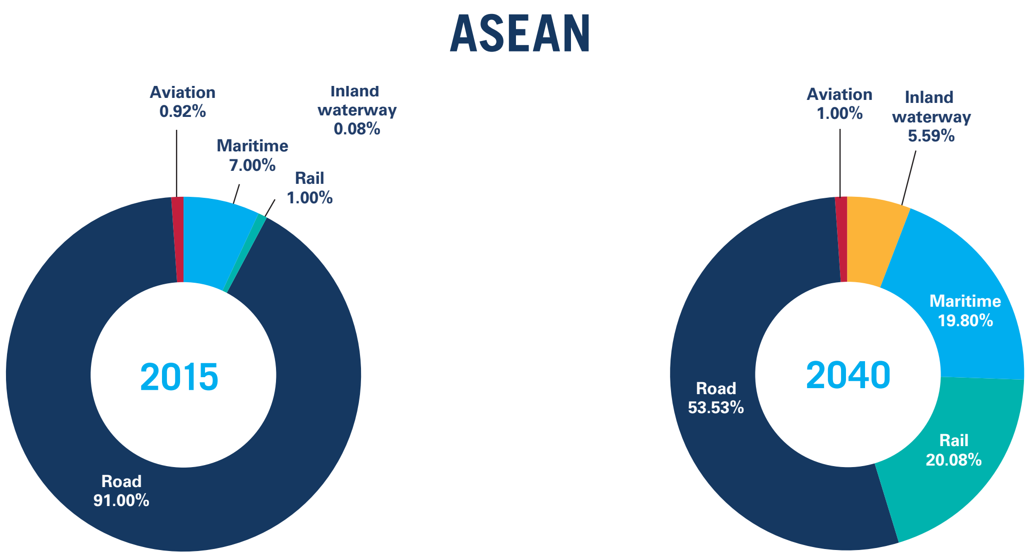
Based on our analysis of future technological developments and possible political initiatives, at the European regional level inland waterways transport will increase in the future. There are two factors behind this trend. First, higher productivity is expected in the future - higher capacity, lower transport time - in the context of deploying autonomous barges in inland waterways and electronic semi-autonomous trucks. Secondly, unit transport cost reduction is expected due to Government subsidies and clean policy considerations.

4.2 MODAL SHIFT IN ASEAN

ASEAN countries (see Figure 2.9) have experienced an increase in rail and waterborne freight movements in recent years. Historically, the inland waterways transport mode had an extremely low market share and was the least developed mode of transport in terms of volume. The situation is expected to change in the future, since the modal shifts in ASEAN countries will be led by emission-control policies and facilitated by infrastructure investment.

More specifically, from 2015 to 2040, ASEAN might expect approximately 19.1 per cent of the total freight previously transported by road to be moved by rail. During the same period, ASEAN might also expect to see substantial increases in maritime transport, including 5.6 per cent by inland waterways and 19.8 per cent seaborne. By then, approximately 0.8 billion ton-miles would be waterborne freight. Subsequently, the projected road transport volume might decrease to 53.5 per cent by 2040, a significant drop from the current 91.0 per cent.

FIGURE 2.9 Modal shifts in ASEAN (2015 and 2040)



Sources: ASEAN StatsDataPortal, WMU analysis and forecast
Notes: Figures relate to freight only. Computations based on tonne-miles. Aviation and maritime cover only intra-ASEAN movements of goods.

Our transport forecast highlights a situation that, while familiar, is a sector that has undergone significant changes, including the introduction of new technologies. Because technology enables quicker and more economic transport, it causes changes in trade patterns and modal shifts. It also influences employment, with professional categories changing due to shifting patterns in trade and in modal shifts.

In summary, the projections in this section on modal shifts at regional level face considerable uncertainty, and hinge on various assumptions which may or may not hold true in the future, for example, autonomous electronic inland barges and strict emission control policies in Europe. The technology forecast (i.e. scenarios taking policy into consideration) for different modes would help to provide inputs and guidelines in that regard. Again, this section contains assumptions for the future.

FINAL REMARKS

Based on the analysis undertaken in this chapter, the following conclusions can be drawn: overall transport volumes are expected to increase, but at a decreasing rate. The development of the global economy will lead to new transport routes. Productivity gained from technological development leads to modal shifts between the four transport modes at a regional level.

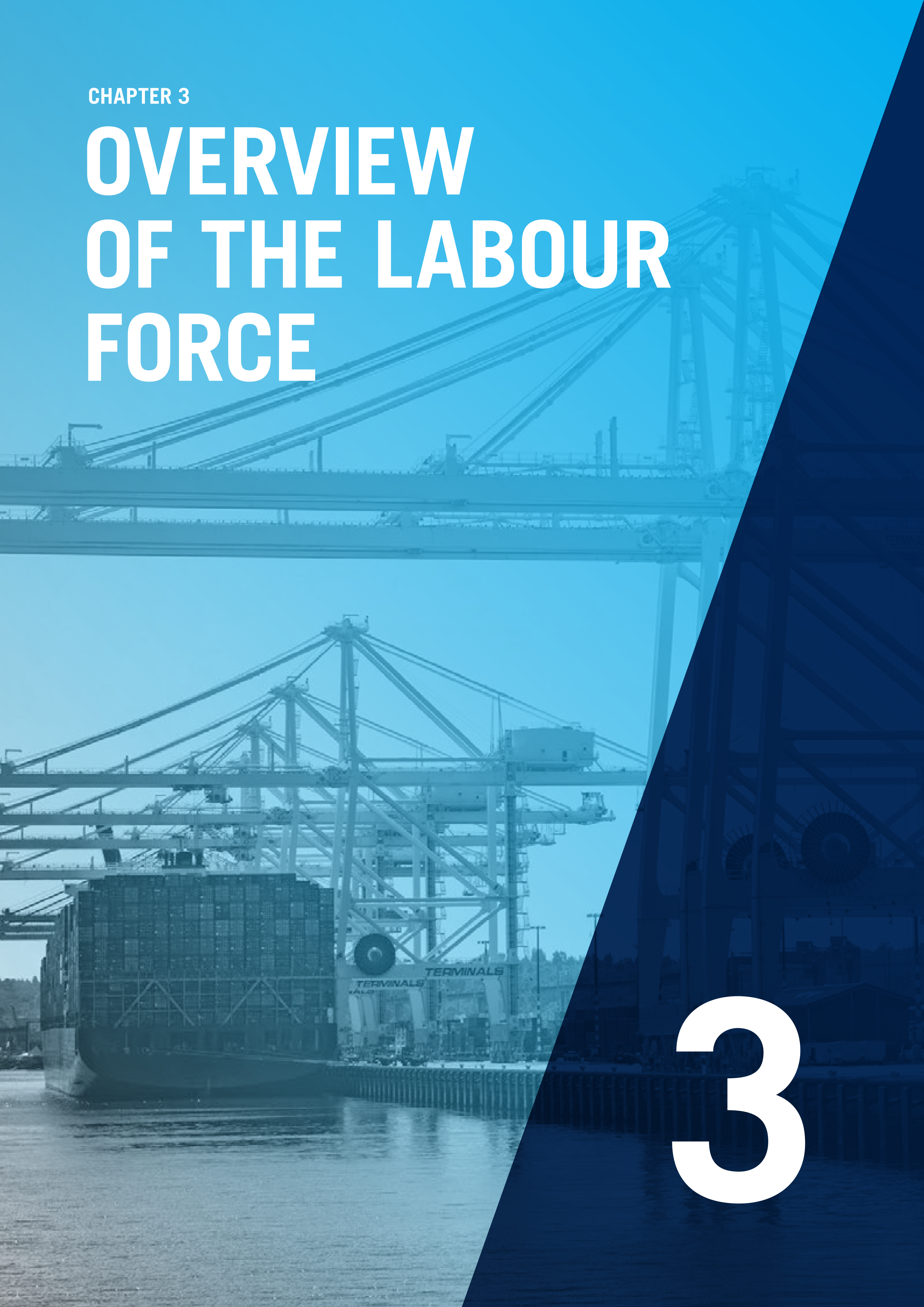
Moreover, this chapter identifies new patterns of future transport. For example, in the Indian Ocean region, the report forecast the rise in the volume of exports and imports and the associated increasing demand of transport.

Taking a broader perspective, Chapter 2 focused both on transport and discussed the implications of the further introduction of technology and automation globally and at the regional level, in particular in the European Union and the ASEAN patterns in future transport and increasing transport volumes were discussed. The chapter demonstrated that technological innovation brings increased productivity, but that trends like modal shifts in transport also bring uncertainty.

In Chapter 3 we turn to the global transport labour force where we will ascertain that the impact of automation and technology on the labour is not uniform. It does not lead to job elimination across the board as is sometimes assumed, nor are all job categories impacted to the same degree.

CHAPTER 3

OVERVIEW OF THE LABOUR FORCE



3

SUMMARY

This chapter provides an overview of the global transport labour force by analysing statistical information from more than 70 countries. The purpose of the analysis is to categorize the labour force participation in the transport sector into different skill groups, and to carry out an assessment of the potential for automation in such groups. By combining the results from previous chapters and data about the transport labour force, several quantitative indicators are cited which show that parts of the transport labour force may be at risks from the increasing use of technology and automation.

The analysis undertaken led to the following key findings:

1. **A similar potential for automation exists in transport as in other industries, but its adoption rate is projected to be slower.**

2. **The share of automatable tasks is much higher in low- and medium-skill jobs than in high-skill jobs.**

3. **The global demand for transport workers will change due to the advances in automation and technology: technology will reduce manpower requirements, but the trend in the expansion of international trade will counterbalance such reduction. Overall, the forecast projects a need for more transport workers in the future.**

4. **The impact of technology and automation on the transport labour force depends on a complex number of factors such as skills, tasks, labour costs or transport modes.**

1 INTRODUCTION

Transport workers represented approximately 5 per cent of all employees in the world in 2017, or about 7 per cent when excluding occupations in agriculture. This proportion corresponds to approximately 168 million direct jobs;[12] 3.3 million jobs are associated with the maritime transport industry alone.[13] These numbers show that the transport sector is the third largest employment sector in the service industries, and plays a fundamental role in the smooth operation of other industries. Although some characterize the transport sector as different from the other sectors, no such differentiation exists in the interlinkage between labour and technology. The transport sector has assimilated technological advances that have substantially changed the industry.

Recently, a lot of attention has focused on certain technologies, which threaten to render a large number of current jobs obsolete, mostly as a result of advances in artificial intelligence, mobile robotics and the declining price of computers. Frey and Osborne (2017) predict that a significant number, namely 47 per cent, of jobs are at high risk of becoming automated in the U.S. economy in one or two decades. This has raised concerns about massive unemployment, and its potentially devastating consequences for economies and societies.[14] Studies following the methodologies suggested by Frey and Osborne have resulted in similar estimates for other developed economies.[15]

[12] Direct jobs refer to those created within the industry, as opposed to indirect jobs, which are created to support the activities of the industry or because of economic spillovers.

[13] The total share of transport employment calculated is based on the countries analysed (see Appendix Table C.1). Transport refers to the ISIC revision 4 "Transportation, storage and communication". The total global employment figure was obtained from the International Labour Organization (ILO) report, entitled "World Employment and Social Outlook: Trends 2018". It was used for the extrapolation based on the calculated share.

[14] Akin to John Maynard Keynes' (1930) idea of technological unemployment. This premise has to date not been observed in the global economy.

[15] See, for example, World Bank (2016) or Chang and Huynh (ILO, 2016).

More recent studies commissioned by the OECD have revised this number down to 14 per cent of the jobs across 21 OECD countries (9 per cent for the United States) facing a high risk of automation with more than 70 per cent of the tasks involved in those jobs being fully automated within the next two decades (see Arntz, Gregory and Zierahn (2016) for more details). Using similar expert judgment about expected technological progress and its negative impact on certain jobs, the two studies have produced figures showing how much uncertainty is involved in predicting the impact of such technologies on the world of work.

The automation of specific tasks will definitely impact labour demand. However, the extent to which unemployment may result from automation and technology is difficult to predict. New technologies and automation are usually introduced with the objective of increasing the output/efficiency of individual employees. Because jobs are a complex bundle of interrelated tasks, the automation of tasks does not result immediately in jobs becoming obsolete. While some jobs will be eliminated, others will be created.

As a World Economic Forum (2018) report recently highlighted, the further use of technologies in the workplace can potentially lead to even more jobs. Market dynamics can also come to play in reconfiguring the workplace during times of automation and increased digitalization. Organizations will shift towards a different balance of workers and machines. Totally new jobs will be created, current job profiles will change significantly. However, the net gain in terms of number of jobs is expected to be positive.

One should also recall that previous chapters projected that the demand for transport services was expected to grow given ongoing positive trends in global trade. This prediction is expected to attenuate the impact of technologies and automation on employment.

To respond to the controversial discussions of the effects of automation and technology on the labour force employed in global transport, this chapter provides a sectoral assessment of relevant trends from the perspective of this worker category. The data covers almost 60 per cent of the global labour force from more than 70 countries. WMU research team has expended considerable effort in collecting official national statistical data on a large number of United Nations Member States, which represent a heterogeneity of national economies.

The aim is to provide a global overview and also to allow for cross-regional and cross-country comparisons. One should note that this study is one of the first to offer a comprehensive picture of the current transport labour force and its future in view of the coming introduction of further automation and technology in this sphere.

The chapter is structured as follows. Section 2 begins by an overview in order to understand the historical relationship between labour and technological progress. At the outset, the Keynesian idea of technological unemployment is introduced which is followed by a review of more recent trends on the polarization of labour markets, the automation of routine tasks and the decline of labour shares in advanced economies.

Section 3 provides one of the most comprehensive profiles of the global transport labour force through its use of official statistics from more than 70 countries. By using estimates about the impact of technology on several occupations over the next two decades, this study provides a benchmark of the risk of automation and computerization of jobs in the economy in general and the transport industry and its related sectors. In this section, an analysis of the relationship between current automation and the expectation about the future is undertaken. A further linkage between labour demographics, labour costs and technical feasibility is analysed and conclusions are drawn.

Industry task profiles are developed and analysed in section 4. The technical bottlenecks for the further introduction of automation and computerization are examined, together with the differences across tasks in the transport sector. Section 5 goes a step further by rendering all the identified factors that influence technology endogenous and provides predictions on its impacts on labour by 2040.

2 THE INTERPLAY BETWEEN TECHNOLOGY AND LABOUR

2.1 INCREASING AUTOMATION OF ROUTINE TASKS HAS NOT RESULTED IN LONG-TERM UNEMPLOYMENT

Recently the relationship between technology and labour received considerable attention as the technologies now under development can automate both more mechanical work processes and cognitive work. The concern that technology can cause significant layoffs is not new. Concerns about technology displacing labour have existed as early as the first Industrial Revolution (Mokyr, Vickers and Ziebarth, 2015). Technological unemployment, a term coined by John Maynard Keynes (1930), has been used to describe unemployment driven by advances in technology.

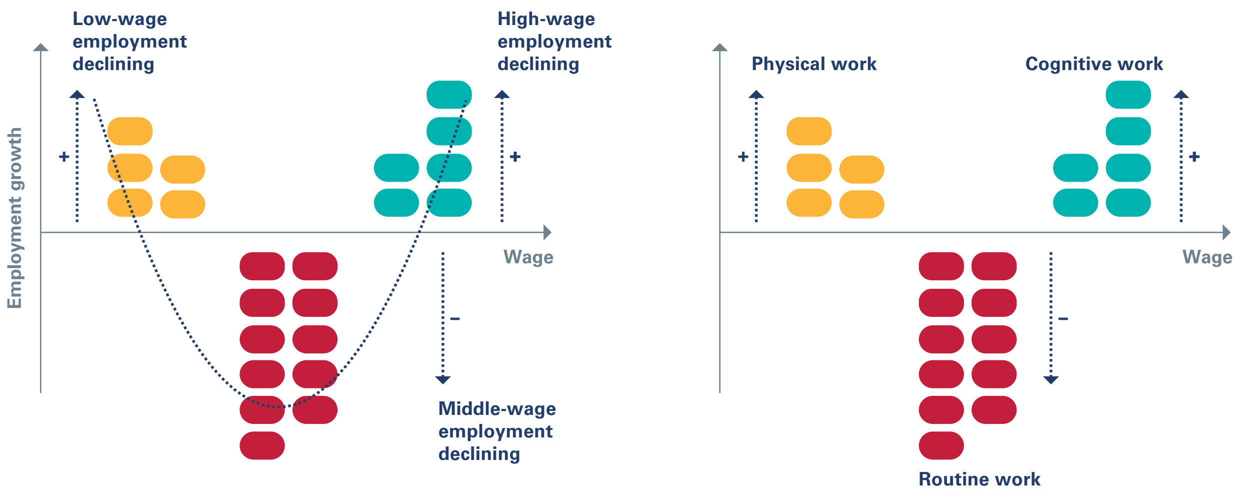
Technological unemployment occurs when new uses for labour are not found sufficiently fast as a counterweight to the loss of jobs caused by technology. Despite several technological advances made over the last decades, no significant rise in unemployment has been attributed to technology in the long-term, nor have Keynes' concerns materialized as yet (IMF, 2018b). However, technology has been driving wage inequality.

Since at least the 1970s, technology has been biased toward more skilled workers. Because new technologies can generally be more easily acquired by those who are highly-skilled and educated, the demand for such workers has been rising in recent decades in parallel with the increasing use of technology in the workplace (e.g. Acemoglu and Autor, 2011). In the process, the wages of high-skilled workers have risen sharply, while middle- and low-skilled groups have lagged behind. More recently, from the 1990s onwards, this trend has become more nuanced, with the demand for workers starting to polarize towards low-skill workers and high-skill and high-earning workers.

INFOBOX 3.A AUTOMATION AND JOB POLARIZATION

Job polarization is a phenomenon characterized by a rise in employment at the bottom and the top of the wage distribution chart. The most advanced economies experienced this trend from the 1990s. As shown in Figure 3.A below, polarized labour markets are characterized by a shift in employment growth in low- and high-wage jobs, while middle-wage jobs disappear. While some nuances might exist based on the specificities of economies, for most countries, polarization means an expansion of physical and cognitive work relative to routine work that is automatable. The consensus is that technology, in particular automation of routine tasks, is the leading cause of polarized labour markets (Acemoglu and Autor, 2011; Goos, Manning and Salomons, 2014).

FIGURE 3.A Employment polarization



Labour market polarization reflects the growth in employment of low- and high-wage workers and the consequent decline in the share of employment of middle-wage workers. The net effect is the hollowing-out of the latter, which is usually associated with rising wage inequality (see Infobox 3.A). Some observers have shown that polarization is mostly driven by automation of routine tasks (e.g., Autor, Levy and Murnane, 2003; Acemoglu and Autor, 2011). The argument behind this is that computers and computer-aided machines can automate routine tasks, those that are particularly intensive in most middle-skilled jobs.

Routine tasks are repetitive and can be accomplished by following a set of well-defined rules and procedures. Machines can be programmed to do the same, but so far with no capability of solving every single contingency. By automating routine task-intensive jobs, labour markets became polarized as middle-wage (and middle-skilled) workers carry out most of the automated routine tasks. While automation technology was initially seen as a substitute mainly for routine tasks, current technological developments challenge this idea.

One outcome of such trends is a rise in wage inequality. Studies suggest that the earnings associated with cognitive tasks are substantially higher than those related to other tasks. As such, the disappearance of middle-wage jobs may have a potentially detrimental effect associated with a shrinking middle-class and the rapid rise in salaries for top income-earners.

2.2 THE RISK OF AUTOMATION FACED BY LABOUR IS LOWER WHEN FACTORS OTHER THAN TECHNICAL FEASIBILITY ARE CONSIDERED

Recently, attention has been drawn to developments in artificial intelligence, mobile robotics and computing power and their ability to dramatically change labour markets. Such technologies do lead to automation of a broader range of tasks (Frey and Osborne, 2017). Several studies have presented assessments based on the study by Frey and Osborne (2017), where a panel of experts evaluated whether specific occupations, 70 in total, were expected to be automated within the next two decades given advances in machine learning, i.e. artificial intelligence, mobile robotics and computer power.

By recognizing automation bottlenecks from a technical standpoint (i.e. perception manipulation, creative intelligence and social intelligence), Frey and Osborne expanded the results to a comprehensive set of occupations (630 in total) that experts did not evaluate directly. The results led to the conclusion that 47 per cent of current jobs in the United States are at high risk of being automated, estimation that brought the issue to the fore in the media, and led to several initial studies and discussions around the future of the workplace.

While several observers found estimates of a similar magnitude, a recent OECD study revised the estimate to a much lower 9 per cent of jobs in the United States at high risk of being automated and to about 14 per cent for a number of OECD countries (Arntz, Gregory and Zierahn, 2016). This significant cross-study variation is an indicator of the high uncertainty the topic engenders regarding which this sectoral report sheds some light on vis-à-vis the transport sector.

Current estimates of workforce automation reflect mostly its technical feasibility. While its technical feasibility, or technological readiness, is a necessary condition for automating labour, it is not a sufficient condition for its widespread adoption. As the World Bank (2016) emphasizes, time lags need to be taken into account in this assessment, especially for countries whose technology absorptive capacity, that is, the necessary conditions to effectively use technology (e.g., business climate, basic technological literacy) are still not sufficiently available.

Furthermore, as the OECD (2018) highlights, even if most job responsibilities can be automated, it is unlikely that all workers performing such a job will become redundant immediately. Therefore, it is unlikely that all highly automatable jobs will disappear. Historically, the number of jobs created by technology outpaces the number of positions eliminated. Gains from increasing productivity have not led to long-term unemployment or reductions in the standards of living, rather most citizens have benefited from technological automation (Autor, 2015).

Even when the automation of most work activities is technically possible, its implementation needs to be economically feasible. Studies have empirically shown that factors, such as the ageing of the population, are determining factors for adopting automation technologies, in particular, manufacturing robots (Acemoglu and Restrepo, 2017). The results show that industries relying more upon middle-aged workers have a greater incentive to automate.

Similar economic arguments can be put forward about current technology. As technology is a driver of the declining share of the labour force (IMF, 2017), even with current technology, further declines in the labour force and income will be experienced if current automation technologies (e.g., information and communications technology or ICT) become cheaper than labour. The price argument is also used as an explanation for the observed job polarization, and it will be an ongoing essential factor in the extent and pace of automation in the future.

2.3 TECHNOLOGY CAN EXACERBATE INCOME INEQUALITY

The role of technology is not limited to labour substitution, but also encompasses labour complementarity. Automation technologies have and are substituting for labour in performing routine tasks i.e. codifiable and repetitive tasks. Highly routine work, such as workers performing machine operations, is experiencing declining labour demand as such activities become redundant. Consequently, workers are forced to shift, mostly to lower-wage and low-skill jobs (Fonseca, Lima and Pereira, 2018; IMF, 2018b).[16] While routine jobs are becoming scarcer, a particular group of workers has benefited from technological advances, namely, high-skilled groups. High-skilled workers and technology have a mutually beneficial relationship, since technology complements their work, enhancing productivity and, consequently, driving labour demand and wages upwards (Acemoglu and Autor, 2011)

Technology can also exacerbate current challenges faced by the labour force. An example of this is the declining share of labour in the world economy (Karabarbounis and Neiman, 2014; ILO and OECD, 2015; IMF, 2017; Ciminelli, Duval and Furceri, 2018). In some countries, like China and Germany, an almost 10 per cent decline in the labour share in the gross domestic product took place in under 20 years (1995-2015). Increasing technology use has the potential to accentuate these trends, followed by labour and capital.

Likewise, the emergence of technology in the workplace facilitates a shift toward more flexible forms of work, with no physical workplace and consequently fewer relations between co-workers. Although appealing for some, the flexible nature of work associated with the gig economy[17] can weaken the bargaining power of workers and reduce their voice. Labour market institutions and policies (e.g. the minimum wage) and the framework of collective bargaining may change. This situation has led some observers to note that new forms of work and the gig economy weaken workers' bargaining powers with possible negative consequences for such workers (OECD, 2017; Johnston and Land-Kazlauskas, 2018).

Such an argument coincides with evidence that declining union membership rates have resulted in weakened bargaining positions (Visser, Hayter and Gammarano, 2017).

Despite all the challenges raised by the increasing use of technology, historically technology has contributed positively to the world's development and brought about more prosperous societies. Evidence-based dialogue and industrial relations that contribute to crafting effective policies promoting decent work conditions, wages and prosperity are essential.

3 GLOBAL TRANSPORT LABOUR FORCE

3.1 MOST TRANSPORT WORKERS ARE MIDDLE-SKILLED AND EMPLOYED IN THE ROAD TRANSPORT SECTOR

Few statistics are available on the distribution of employment within the global transport sector. Currently available statistics are either localized or not detailed enough to provide a true picture of labour distribution patterns. This sectoral assessment of the transport sector's labour force is one of the first to provide a comprehensive overview. In that regard, it covers almost 60 per cent of the global labour force from more than 70 countries. The global transport labour force statistics were obtained from official labour force data collected from a wide range of countries and covering all regions around the globe.[18] Hence, the information collected provides one of the most comprehensive profiles of the transport labour force available to date.

In Figure 3.1 employment distribution by transport mode is summarized, together with the gender participation rate in the labour force.[19] The statistics show that road transport is the most labour-intensive sector, employing about 82 per cent of the global transport workforce, or about 138 million workers, when extrapolating for the global workforce.[20] Road transport alone accounts for about 92 per cent of land transport, while the remaining 8 per cent is rail transport.[21]

Multi-modal support activities (e.g., ports, airports, warehouses) account for approximately 14 per cent of the transport labour workforce. Due to the unavailability of data, a further breakdown by mode for support activities is not possible. Thus, throughout the subsequent analysis, these are called support activities and they are not tagged to any specific mode.

The labour employed by the air and sea transport industries account for similar employment shares of about 2 per cent, or about 3.3 million workers each, when extrapolating for the

[16] See Infobox 3.B for details on the classification of the skill levels and examples of occupations related to each of the groups.

[17] Work that is based on online platforms, service oriented and usually based on short-term contracts or freelance work.

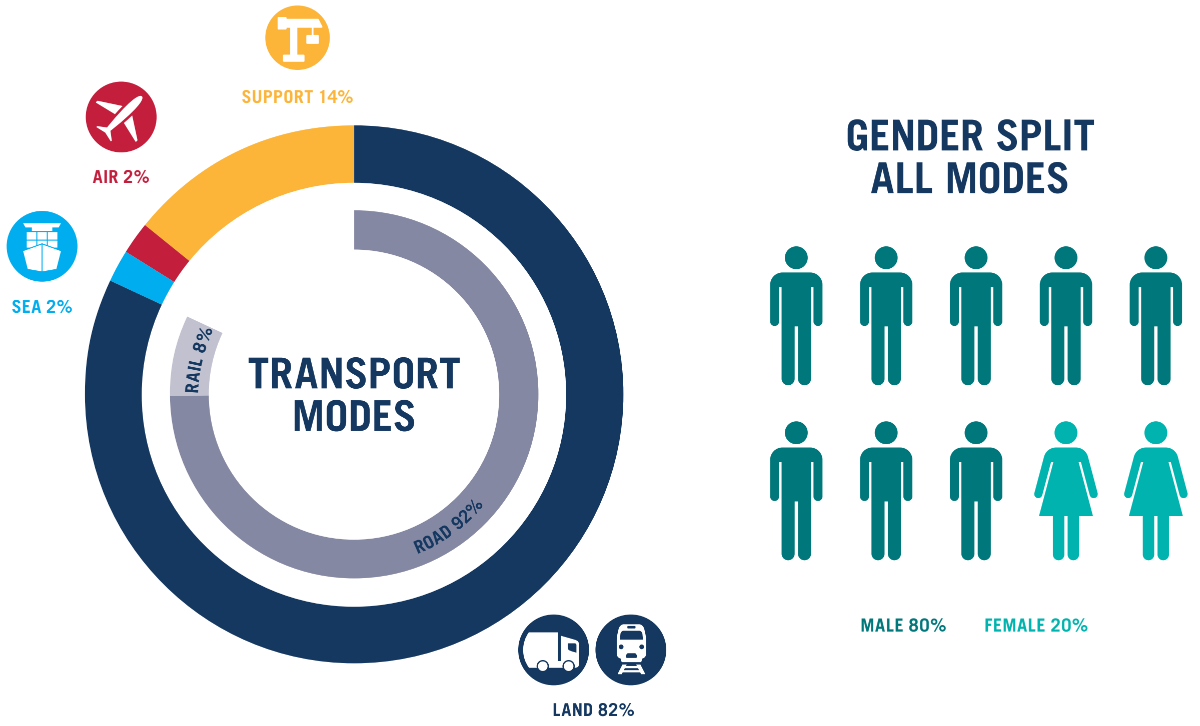
[18] For the detailed list of the country and year used in the analysis see Appendix Table C.1. For some countries earlier years were used when 2016 was not available.

[19] The transport industry corresponds to ISIC rev.4 code H "Transportation and Storage". The breakdown into several modes refers to the following codes: land (ISIC 49, excluding 493 when possible), sea (ISIC 50), air (ISIC 51), multi-modal support activities (ISIC 52). Because of statistical confidentiality, in this report, we cannot further break industry codes. The numbers provided are the best available to provide a snapshot of the global workforce. However, the statistics are not detailed enough to draw micro-level conclusions. For example, the category sea (ISIC 50) includes workers other than seafarers.

[20] The extrapolations are based on the employment shares calculated and the total employment figures, as referred to in Footnote 13.

[21] Employment shares for rail and road are intended to provide only a rough estimation as the official numbers cannot be obtained for most countries. The calculations were performed using a small sample of countries and regions (European Union 28, Ghana, United States). Thus the numbers should be carefully interpreted and used.

FIGURE 3.1 Employment distribution across the different transport modes



Sources: Bureau of Labour Statistics (BLS), Eurostat, ILO, WMU Analysis
Note: For the complete list of countries used see Appendix Table C.1.

global workforce. In Figure 3.1 the gender composition of the transport sector was plotted. It is clear that the female participation rate is lower than for males, with almost four out of every five workers being male.

The distribution of skills across the transport sector is not uniform (for example see Infobox 3.B where jobs are grouped in skill categories). In bottom panel of Figure 3.B (Infobox 3.B), we plot the distribution of skills for each transport mode and support activities. The medium-skilled group, as defined by the ILO (2012), represents the most considerable segment of the global transport labour force, accounting for more than 72 per cent. Even under the current trends of polarization of labour markets (see section 3.2.1), this group is still sizeable enough to prevail in transport. The low- and the high-skilled groups have similar employment shares of approximately 15 and 12 per cent respectively.[22] The reliance on middle-skilled labour is evident over the different transport modes. The statistics indicate that over half of transport sector jobs are middle-skilled. This fact applies across the different transport modes with the size of the middle-skill group depending on the transport mode. Land transport relies the most on middle-skilled labour (about 76 per cent), followed by sea transport (62 per cent).

While low-skilled jobs are more prevalent than high-skilled ones in land transport and multi-modal assistance activities, this dynamic is reversed for sea and air transport. More than 28 per cent of the jobs in sea and air transport are high skilled, with the low-skill jobs not surpassing 10 per cent in total. The variability found in the skill composition points toward the similarities between sea and air transport when it comes to automation and to a different automation schedule when it comes to land and multi-model support activities.

[22] ILO (2012) group occupations are graded according to skill levels of 1 to 4. Following the best practices in the field, this report refers to the various skill levels as low (level 1), medium (level 2) and high skill (levels 3 and 4). The international standard classification of occupations (ISCO), maintained by the ILO, is used to classify jobs into a pre-defined set of broader groups according to the tasks and duties performed in specific jobs. Occupational groups (ISCO-08) are categorized as low skill, ISCO code 9 (Elementary Occupations); medium skill, ISCO codes 4 (clerical support workers), 5 (Services and Sales Workers), 6 (Skilled Agricultural, Forestry and Fishery Workers), 7 (Craft and Related Trade Workers), 8 (Plant and Machine Operators, and Assemblers); high skill, ISCO codes 1 (Managers), 2 (Professional), 3 (Technicians and Associate Professionals). This classification is used for easiness in referring to the different occupational groups and it does not constitute a true measurement of complexity, schooling level and training required to undertake a certain job. In most cases, there is a strong correlation between skill and income: high-skill are usually high-income jobs, medium-skilled are middle-income and low-skill are low-income. However, these facts can vary from country-to-country.

INFOBOX 3.B SKILL, OCCUPATIONS AND WORK ACTIVITIES

PANEL A

TRANSPORT WORKERS

LOW SKILL	MEDIUM SKILL	HIGH SKILL
15%	72%	12%

OCCUPATIONS

LOW SKILL

BAGGAGE HANDLER
WAREHOUSE PORTER
DOCK WORKER

FREIGHT HANDLER

- Move materials, equipment, or supplies
- Sort materials or objects for processing or transport
- Load shipments, belongings, or materials
- Mark materials or objects for identification

...

MEDIUM SKILL

CRANE OPERATOR
FORKLIFT OPERATOR
SHIP RATING

HEAVY TRUCK DRIVER

- Operate vehicles or material-moving equipment
- Follow safety procedures for vehicle operation
- Inspect cargo to ensure it is properly loaded or secured
- Secure cargo
- Monitor cargo area conditions

...

HIGH SKILL

AIR TRAFFIC CONTROLLER
SHIP ENGINEER
SHIP OFFICER

AIRLINE PILOT

- Pilot aircraft
- Communicate with others to coordinate vehicle movement
- Monitor equipment gauges or displays to ensure proper operation
- Notify others of emergencies, problems, or hazards
- Respond to transportation emergencies
- Record operational details of travel

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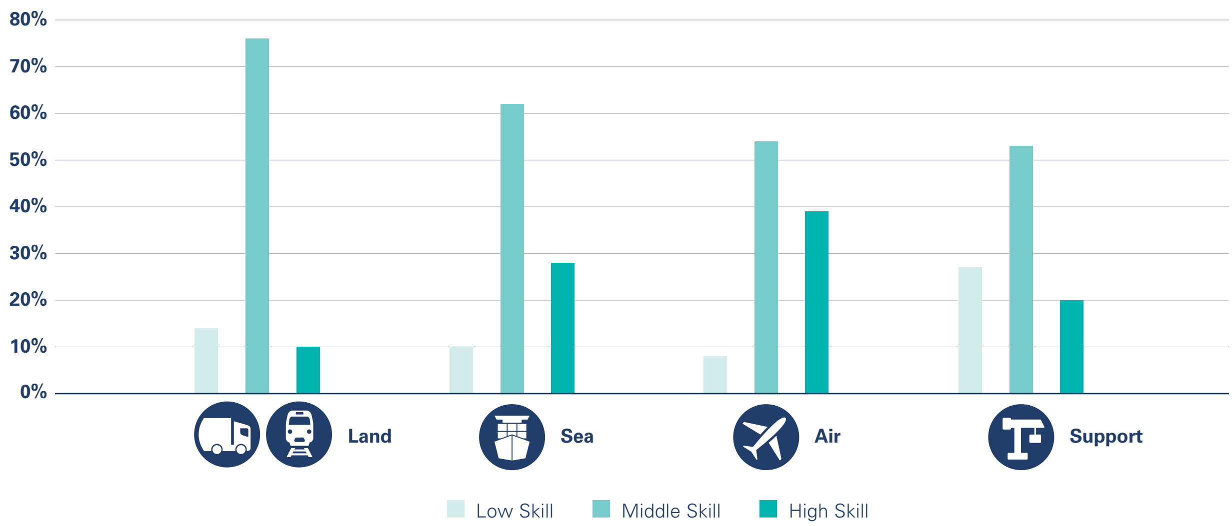
PANEL B

DISTRIBUTION OF WORKERS OVER TRANSPORT MODES



Sources: BLS, Eurostat, ILO, WMU Analysis

Notes: For the complete list of countries and sources used see Appendix Table C.1. Calculation for the share of workers based on countries and sources referred to in table. The grouping of occupations into skill groups follows the ILO (2012). Work Activities are based on O*Net. Numbers may not add up to 100% due to rounding.

3.2 LOW AND MIDDLE-SKILLED WORKERS HAVE A HIGHER POTENTIAL OF BEING REPLACED BY TECHNOLOGY

Technology and automation affects workers' groups differently depending on their occupation, among other factors. Occupations are usually aggregated into the three skill groups used heretofore: low, medium, and high. Historically, technology affects some skill groups more than others, especially in terms of job displacement through job substitution. A comparative analysis of the potential for automation by skill group was performed to assess the extent to which today's jobs are at risk of being superseded by technology in the future.

The research benchmarks transport workers with their counterparts in other industries. The aim of this exercise is to make a critical comparison to develop a shared understanding of the changes to come, and to enable similar challenges to be tackled using a broader knowledge of the implications of technological change. For that purpose, this study employed a commonly used methodology to evaluate the potential for job automation, based on an expert assessment of the anticipated advancement in automation technologies, such as artificial intelligence and mobile robotics, in conjunction with the declining price of computing power.[23] See Infobox 3.C regarding the growing interest and investment in those technologies.

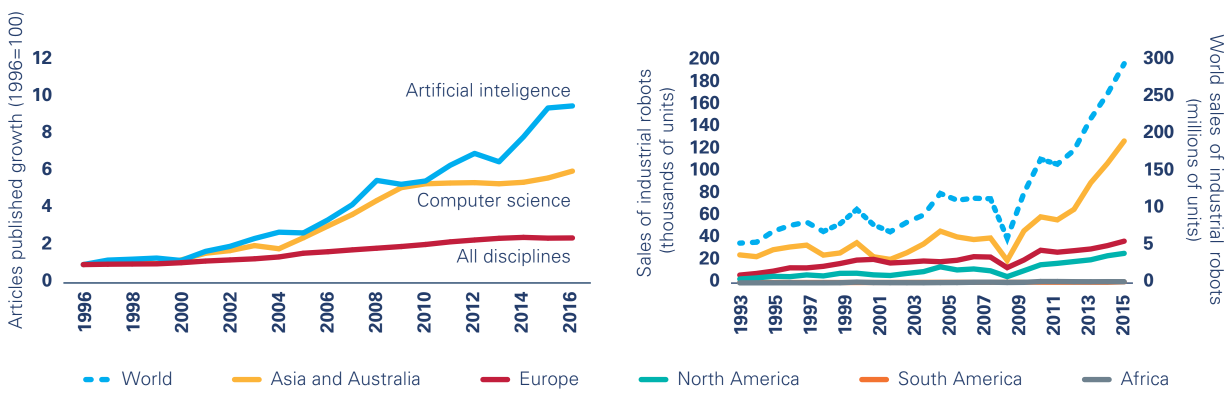
Figure 3.2 shows the potential for automating tasks by 2040 among different skill groups measured by the employment-weighted probability of the job being carried out by technology based on Frey and Osborne's (2017) methodology. On average, the transport sector has a similar potential for automation as other industries, which is especially high for the low- and medium-skilled groups of workers. The high rate of automation means that values estimated for the low- and medium-skilled groups (over 68 per cent) contrast with the less than 6 per cent figure calculated for the high-skilled group. However, even within the skill groups, some substantial variance exists as expressed by the minimum-maximum bars (in white). These results indicate that technologies and related applications to be introduced in various industries will also affect job profiles in transport.

INFOBOX 3.C STRONG INTEREST IN AI AND ROBOTICS IS ALSO REFLECTED IN THE STATISTICS

The recent attention paid to AI and robotics is also demonstrated in research and companies' investments. The sharp increase in AI research over recent years far surpasses the speed of research in computer science and scientific articles in general (see Figure 3.C, Panel A). A similar momentum is also observed in the sales of industrial robots, whose growth rate has dramatically increased over the last decade (see Figure 3.C, Panel B).

FIGURE 3.C AI research and Industrial Robots

Panel A – AI research **Panel B – Industrial Robots Sales**



Source: Scopus, AIIndex, WMU analysis

Source: International Federation of Robotics, WMU analysis

[23] Relevant studies (e.g., Change and Huynh, 2016; World Bank, 2016) have used similar methodologies based on the Frey and Osborne (2017) study.

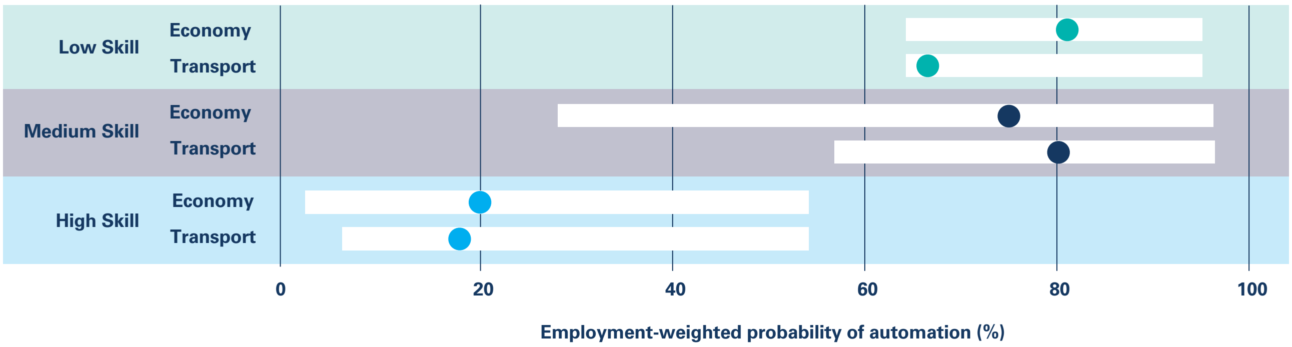
It is important to highlight that the estimates presented call for careful interpretation, a recommendation that has been disregarded by some. That is, even when an occupation has a high probability of being replaced by technology, it does not signify that all workers in that occupational group are automatically displaced. The implication is that there is a large number of tasks in an occupation that are likely to be automated and, consequently, with other conditions remaining the same, some jobs will be eliminated as a result of increased worker productivity.

However, the estimates presented are solely based on technical feasibility, and do not consider other relevant factors such as the economic benefits (or lack thereof), or the regulatory framework. The research undertaken shows that such factors lead to different implementation schedules within and across industries. Therefore, the pace by which the introduction of automation technologies takes place varies from industry to industry.

Using the same methodology, we delve into the transport sector comparing the potential effects of technology across transport modes. Figure 3.3 summarizes the results by breaking down transport into land (road and rail), sea, air and multi-modal support activities (e.g. storage and warehousing or cargo handling).[24]

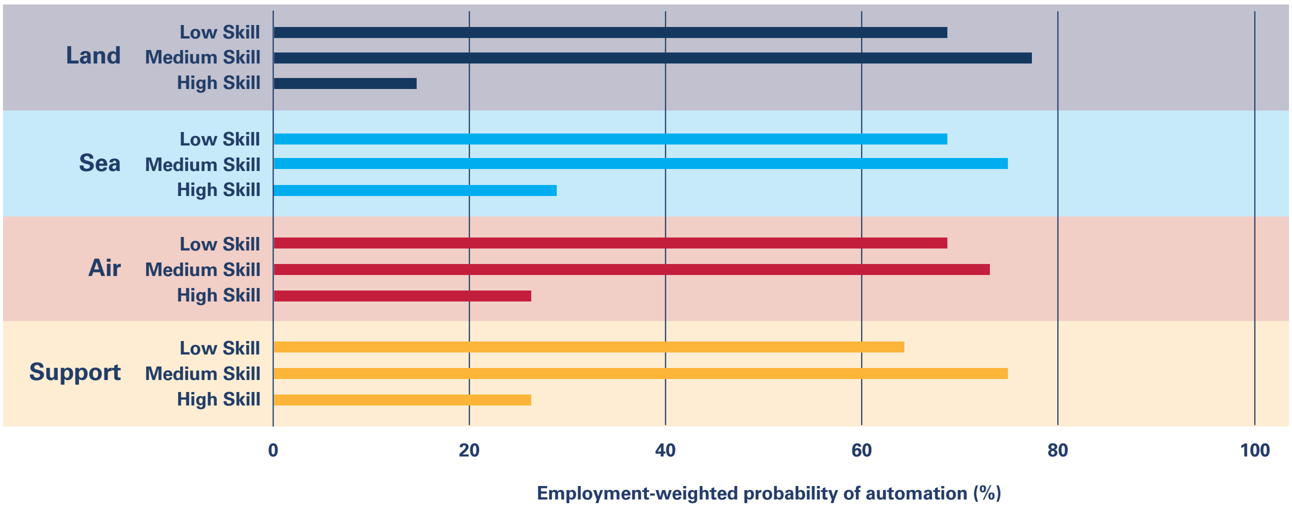
The results indicate that skills rather than the industry are the primary factor behind differences in any automation potential. However, as explained in detail in the previous chapters, the pace of adoption and diffusion of technology varies from industry to industry. These two results clearly underscore that the automation of tasks will come at a different time and speed depending on the transport mode, even when the potential for task automation is similar.

FIGURE 3.2 Automation potential in relation to skill groups in transport



Source: Frey and Osborne. Tech. Forecast. Soc. Change. 114 (2017), BLS, ILO, Eurostat, WMU analysis
Note: For the complete list of countries used see Appendix Table C.1.

FIGURE 3.3 Automation potential in relation to skill groups by transport mode



Source: BLS, Eurostat, ILO, Frey and Osborne (2017), WMU analysis
Note: For the complete list of countries used see Appendix Table C.1.

[24] Due to statistical confidentiality and data availability constraints, we cannot give results for road and rail separately. However, given the results found across the different modes, it is safe to assume that the profile for rail and road do not vary substantially in regard to the technical feasibility of automating tasks.

Currently mostly low- and medium-skilled workers perform automatable tasks. While foreseeable technologies have the potential to automate part of the tasks carried out by high-skilled workers, the historical trends previously discussed do not point to the obsolescence of high-skilled labour. The opposite has happened: the increased use of technology is benefiting high-skilled workers. However, the research undertaken points to low- and medium-skilled jobs being most susceptible to automation.

Figure 3.3 shows that the employment-weight probability of automation is approximately 68 per cent for all types of low-skilled jobs, and 77 per cent for medium-skill jobs. The most significant difference is registered between those two groups and the high-skill jobs, where the probability is estimated to be between 23 per cent (land) and 30 per cent (support). Hence, a significant variation is found when comparing the probability of automation of the low- and middle-skilled groups with the high-skilled group: the difference is about 40 per cent. One should note again that the estimated values relate only to the technical potential. The implementation schedule for the introduction of automation technologies depends on factors other than technical feasibility.

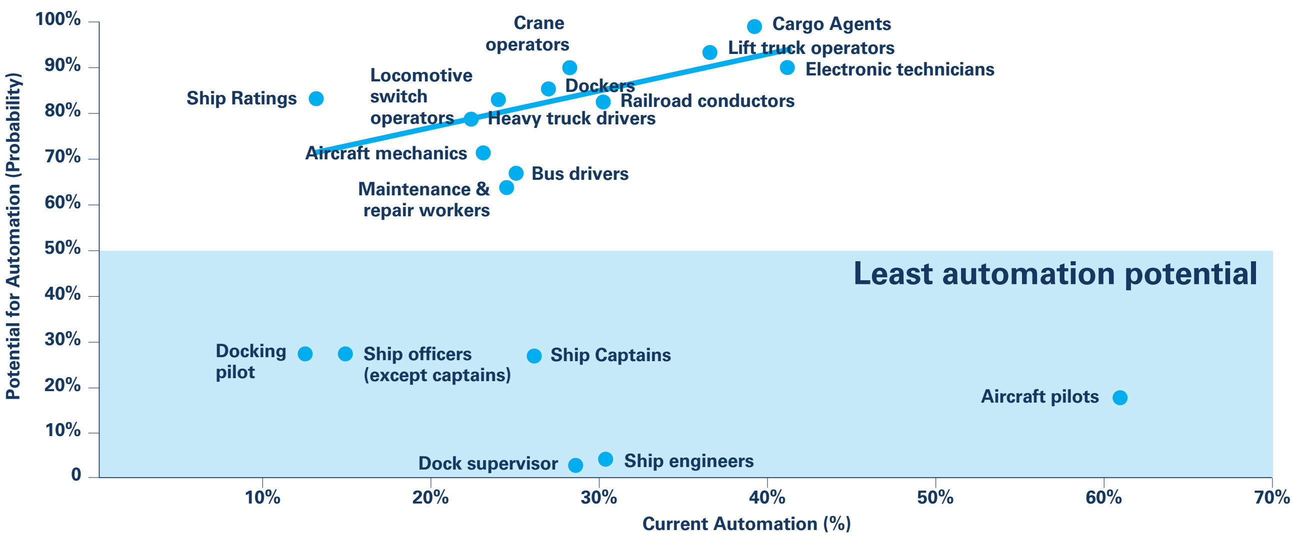
3.3 THE RELATIONSHIP BETWEEN CURRENT AND FUTURE AUTOMATION IS LINEAR FOR SOME JOBS

The current labour force is already experiencing the effects of automation technologies. Depending on the job, a larger or smaller portion of tasks carried out by transport workers is already automated. A countrywide survey shows that for the United States some occupations have more than 50 per cent of their work already automated (e.g. aircraft pilots), whereas automation does not surpass 15 per cent for other occupations (e.g. docking pilot).[25] In Figure 3.4, we plot the current automation levels (horizontal axis) reported for a vast number of transport jobs against the potential for further automation (vertical axis). The potential for automation is assessed from a technical perspective, that is, if one does not take into account the economics of automation.

The graph shows that low- and middle-skilled occupations have the most potential for automation, even when the number of tasks currently automated is limited to a few. For example, maintenance and repair workers are estimated to have one-quarter of their tasks currently automated, yet in the next two decades technology is expected to displace almost two-thirds of their current tasks. The same applies to dockers, where approximately 27 per cent of their current work is estimated to be already automated. Further automation of nearly 85 per cent of their tasks is projected to be technically possible by 2040. This number can reach 90 per cent for crane operators.

In contrast, high-skilled occupations, such as aircraft pilots, docking pilots, ship masters or dock supervisors, are not expected to have more than 35 per cent of their work activities automated. For this latter group, no significant correlation between current automation levels and the introduction of further automation was found.

FIGURE 3.4 Automation potential for job profiles in transport



Source: Sources: Frey and Osborne. Tech. Forecast. Soc. Change. 114 (2017), Occupational Information Network (O*Net), WMU analysis

Note: The blue line corresponds to a linear regression (y=0.81x+0.60; R2=0.37). The sample for the regression includes the subject of transport occupations that are plotted and that have a more than 50 per cent potential for automation.

[25] Current automation is measured by the O*Net Work Context scale "Degree of Automation". The potential for automation is based on Frey and Osborne (2017).

The sharp dichotomy between low- and medium-skilled vis-à-vis high-skilled jobs in regard to automation is highlighted in Figure 3.4. The first group is represented at the top of the chart and the latter at the bottom. From a technical perspective, the current degree of automation can be considered a good predictor of future automation for the occupational groups at the top of the figure (mostly low- and middle-skilled), but not for those at the bottom (mostly high-skilled). The figure shows that for this first group of jobs (e.g., dockers, crane operators or truck drivers) the higher the degree of automation today, the greater the chances of further automation by 2040. Consequently, most tasks involved in such jobs will become obsolete.

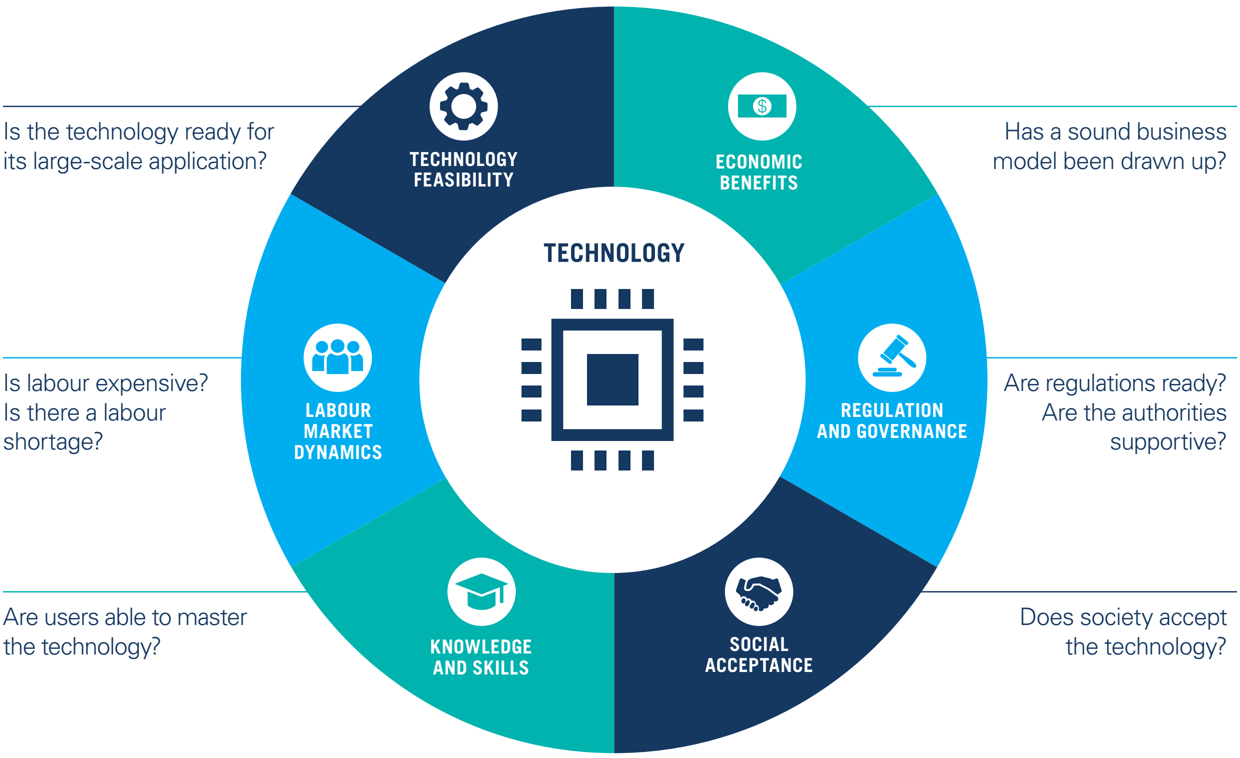
As may be expected, the further introduction of automation technologies that are expected to make some low- and middle-skilled jobs redundant will vary from country to country as factors other than technical feasibility come into play (see Infobox 3.D). Conversely, this positive linear relationship between current automation and further automation is not observed in the high-skilled group (e.g., ship captains, officers and aircraft pilots).

Figure 3.4 points to the hypothesis that current vehicle, infrastructure and systems design open the door for the automation of tasks performed by low- and middle-skilled workers, whereas tasks performed by the high-skilled group are least prone to automation under the current technological paradigm.

The introduction of radical innovations can change this picture. However, our research finds no evidence supporting the obsolescence of high-skilled work activities. For this group, automation and technology are often introduced to assist them, so that individuals can concentrate more on their core tasks. The objective is to complement their work rather than replace them, whereas for the other groups a significant proportion of core tasks can be automated by 2040.

INFOBOX 3.D THE SIX FACTORS THAT DETERMINE THE ADOPTION OF TECHNOLOGY

WMU RESEARCH HAS IDENTIFIED SIX MAIN FACTORS THAT CAN ACCELERATE OR DELAY THE ADOPTION OF TECHNOLOGY



3.4 SKILL COMPOSITION OF LABOUR ACROSS REGIONS LARGELY INFLUENCES THE AUTOMATION POTENTIAL

The previous analysis has been extended to different geographical regions and their skills distribution and the respective average risk of employment-weighted automation has been calculated. The estimates are summarized in Figure 3.5. The figure shows that all geographical regions rely mostly on medium-skilled labour, a group particularly subject to current and future automation. The statistics show that a concentration on middle-skilled work is pervasive across all regions.

Nevertheless, the degree to which the economies rely on middle-skilled work varies by about 14 percentage points. Africa (87 per cent) and Latin American and the Caribbean (81 per cent) are the regions that rely most on middle-skilled labour, whereas the share of middle-skilled workers is lower for other regions, accounting for less than 73 per cent. Labour saving technologies are expected to strongly impact both middle-skilled and low-skilled groups. Nonetheless, the shares of employment associated with this group are much smaller, ranging from 7.8 per cent in Europe to almost 22 per cent in North America.

The skill composition of the current labour force opens the door for increased automation aimed at substituting tasks. Regions relying more on high-skilled labour, such as Europe (19 per cent of jobs are high-skilled), may experience less profound effects than geographical areas relying more on low- and middle-skilled labour, such as North America or Africa (share of middle-skilled employment is 12 per cent and 4.7 per cent respectively). The research undertaken suggests that the potential for automation is around 67 per cent for the low-skilled group, 77 per cent for the middle-skilled group and 29 per cent for the high-skilled group. The numbers reflect the potential for task substitution, and not the direct effects on labour demand.

The figures cannot be interpreted without considering the socio-political and economic context. For example, the economics of automation are missing from the estimates. Although most regions have economies based on middle-skilled labour, the price of labour (wages) and other factors together come into play when implementing the technology. As previously noted, those factors significantly influence the adoption and the pace of the diffusion of technology. For example, research has shown that the ageing of a population can promote the introduction of automation to overcome labour shortages (e.g., Acemoglu and Restrepo, 2017).

In addition, high-wage workforces face a greater risk of being impacted by a higher degree of automation, while the economic incentives for automation are less advantageous for the younger and/or lower-wage workforce. Consequently, the variation in the socioeconomic and demographic composition of the different countries leads to variations in the implementation schedule of automation across different geographic regions, although a similar high technical automation potential exists across all regions.

FIGURE 3.5 Regions relaying more on low- and middle-skilled labour have a higher potential for automation

Sources: BLS, Eurostat, ILO, Frey and Osborne (2017), WMU analysis
Note: For the complete list of countries used see Appendix Table C.1

3.5 ECONOMIC FACTORS AFFECT THE AUTOMATION SCHEDULE

To better depict how economic factors can interplay with automation, this report will focus on several economic indicators in the regions. These include, in particular, measures for labour costs (average earnings), the share of workers above 45 or 50 years and the potential for automation and computerization of tasks. Table 3.1 summarizes the statistics for the different regions.

The second column in the table contains the standardized average earnings from 2014 to 2016. The table shows that North America and Europe represent the regional with higher labour costs, while labour is less costly in Africa. The subsequent columns show estimates for each transport industry (land, sea, air and multi-modal support activities).

The land transport sector has a considerable potential for automation across all regions. For example, Europe's potential has a threshold of 70 per cent. However, by adding the corresponding age profile, different trends arise. North America has the most potential for land transport automation – high automatable task profiles, high labour costs and a high share of older workers. Europe also has significant potential for road automation, especially because of its ageing workforce.[26]

The economic benefits of automation associated with sea transport are overall smaller than those found in other transport modes. The technical potential for automation is lower than in other modes, and the workforce is relatively young. In terms of age distribution, seafarers, in particular ratings, are a relatively young group, which means their age structure does not provide any incentive for automation. While officers tend to be older, they are still relatively young. More than 50 per cent of operational-level officers are under 31 years old, and about 40 per cent of officers at the management level are 40 years old or younger.[27]

Air transport and multi-modal support activities have, on average, a less appealing profile for automation than land transport. However, because of the prevalence of older workers in North America and Europe, automation is expected to affect the industry. As described in the previous chapters, automation is often introduced to overcome a shortage of qualified workers. An ageing workforce is usually an indication of such a shortage. Thus, age structure alone is frequently the trigger for accelerating the diffusion of automation technologies in the industry.[28]

To summarize, this report points out that in regard to transport sector automation, its first large-scale introduction will take place in road transport, especially in passenger transport, as highlighted in Chapter 1, followed by multi-modal support activities in North America. The transport mode profiles of other regions suggest that automation will occur at a later stage in these areas.

TABLE 3.1 Benchmark of the determinants of automation

REGION	LABOUR COSTS	(%) EMPLOYMENT AGE >45 OR >50				TECHNICAL FEASIBILITY			
		Land	Sea	Air	Support	Land	Sea	Air	Support
Africa	-0.8	21	18	21	22	H	M	M	M
Asia and Pacific	-0.6	26	32	26	25	H	M	M	M
Europe	0.6	37	30	29	30	M	M	M	M
Latin America and the Caribbean	-0.7	37	37	15	30	H	M	M	M
North America	1.5	55	37	55	50	H	M	M	H

Sources: BLS, Eurostat, ILO, Frey and Osborne (2017), WMU analysis

Notes: For the complete list of countries used see Appendix Table C.1. Labour costs were measured by the average earning (standardized values) for the whole transport industry. The age used was >50 for all regions expect Europe where >45 was the figure used due to data limitations. Technical feasibility measured by the probability of automation: high (H) when over 70 per cent; medium (M) between 30 and 70 per cent; low (L) when less than 30 per cent.

[26] See Appendix Figure C.1 for the age distribution of the land transport workforce.

[27] The age distribution of sea transport workers in general and seafarers, in particular, can be found in Appendix Figure C.2 and Figure C.3.

[28] For the age distribution of air transport and multi-model support activities see Appendix Figure C.4 and Figure C.5.

3.6 THE VARIANCE IN JOB CONTENT ACROSS COUNTRIES LEADS TO DIFFERENCES IN THE NUMBER OF JOBS AT HIGH RISK OF AUTOMATION

The probabilities of job automation presented in this report are constructs drawn from data collected and extrapolated by Frey and Osborne (2017) that are based on technical feasibility and expected technological developments. The data reflects the international best practices on task-based methods, that is, the report uses O*Net data. While O*Net represents the most detailed repository of tasks and skills of the job (occupational), it is based on U.S. jobs. In this subsection, we empirically show that there is a substantial degree of cross-country variation for the same job titles. The report relies on data drawn from an extensive survey coordinated by the OECD Programme for the International Assessment of Adult Competencies (PIAAC) survey.[29]

The report focused in particular on six of the countries assessed later in Chapter 4: Denmark, France, Japan, Norway, South Korea, and Sweden. All six are arguably at the forefront of technological development, therefore one could have similar expectations about the magnitude of the impact of automation on jobs. The results show the opposite: there is substantial cross-country variation for the same skill group in regard to the share of employment at high risk of automation.[30]

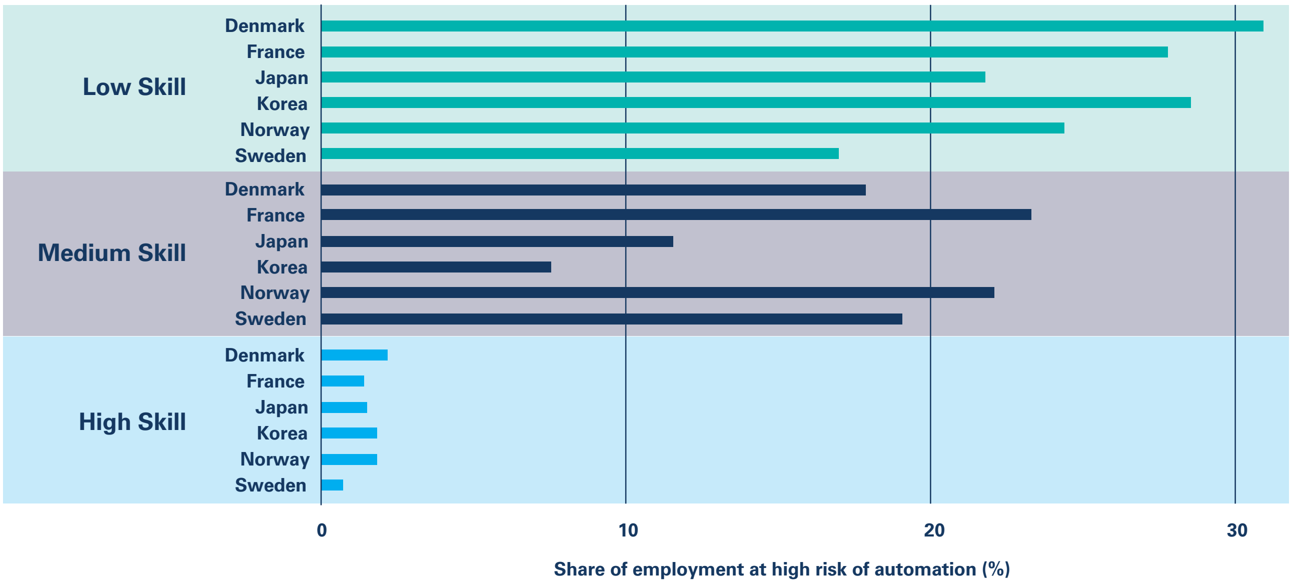
In Figure 3.6, we plot the employment sectors at high risk of automation (70 per cent or higher) by skill group, which were calculated using economy-wide statistical PIAAC data. The results show that that between 5.7 and 50 per cent of low-skilled workers (e.g. dockers, baggage handlers) are exposed to a high risk of automation as more than 70 per cent of the tasks are automatable. Indeed, by 2040 their jobs will not exist in their current form.

The estimates vary significantly between countries. For example, 16 per cent of low-skilled workers in Sweden face a high-risk of automation, while in Denmark, its neighbour, the figure is almost double 31 per cent. The same applies to the middle-skilled group (e.g. able seafarers and heavy truck drivers), where the share of employment at high risk of automation is as low as 7 per cent or as high as 23 per cent, depending on the job responsibilities. The medium-skilled group representing the lowest share (7 per cent) is the Republic of Korea and the highest (23 per cent) is France.

What is consistent across countries, however, is the relatively small proportion of jobs, not exceeding 2 per cent, involving high-skilled workers that are at high risk of automation. The high-skilled group (e.g. ship officers, aircraft pilots and professionals) has the least estimated job losses resulting from the introduction of automation technologies.

However, some variation exists within country-skill groups that is not shown in the Figure. For example, the difference between some occupations within the low-skilled group exceeds 30 percentage points in Denmark, or 51 percentage points in France. The average variation for the middle-skilled group is 33 percentage points and about six percentage points for the high-skill group in the two countries respectively. Such estimates clearly show that differences exist within and across country skill groups therefore close examination of country profiles is necessary, especially when considering factors other than technical feasibility. The magnitude of the estimates is affected when considering the factors referred to in Infobox 3.D.

FIGURE 3.6 Variation of automation risk across skill groups



Sources: Arntz, et. al. OECD Social, Emp. and Migration WP. 189 (2016), WMU analysis
Note: Economy-wide estimates.

[29] The PIAAC survey includes a wide range of countries, whose adult skills are assessed. The data is harmonized which allows for comparisons across countries. Because of the strict confidentiality policies, it is not possible to identify transport workers. However, as shown heretofore, from a technical standpoint, automation technologies have the potential to affect workers in different industries with a similar impact. Therefore, the lessons learned from economy-wide data estimates are informative in terms of the changes they forecast will come to the transport sector.

[30] Calculations are based on the results of Arntz, Gregory and Zierahn (2016, 2017). A high risk of automation refers to an automatability rate of at least 70 per cent.

4 INDUSTRY TASK PROFILES

Extant research has shown that automating both all work-related contingencies and the performance of the more complex physical activities is a challenging impediment to overcome. Computerization bottlenecks, such as social intelligence, creativity, perception and manipulation, can dramatically reduce the likelihood of a job being automated (Frey and Osborne, 2017). Given that a job is a bundle of tasks, if one bottleneck acts as a barrier to automation, the combination of several bottlenecks can even more dramatically reduce the likelihood of a job becoming automated in the next 20 years.

Using the same three bottlenecks to computerization and using data only available for the United States, calculations were made to determine the extent to which the transport sector is affected by the bottlenecks. The average estimates are summarized in Table 3.2, where the three dimensions are measured on a scale ranging from one to five. On average, the transport sector scored below the middle-scale point of three in all categories: perception and manipulation, creative intelligence and social intelligence. These scores are not significantly different from those found for the whole economy. This similitude once again indicates that automation is mainly determined by factors other than technical feasibility when the transport sector is compared with other economic spheres.

To further clarify how work is performed, the report examines the tasks involved in different jobs carried out by transport workers more closely. This exercise shows similarities across task profiles for sea, land and air transport in regard to the complexity and frequency of the tasks involved. Using the same data source, the report analysed around 2,000 work activities across all occupations, which were aggregated into six categories. The scores in Figure 3.7 are composite indicators of how complex and how unlikely a task is for six dimensions. The underlying observed assumption is that less frequent and more complex work is unlikely to become automated in the next 20 years. Thus, work categories with a high score are less likely to become automated, whereas those with low scores are more likely to be.

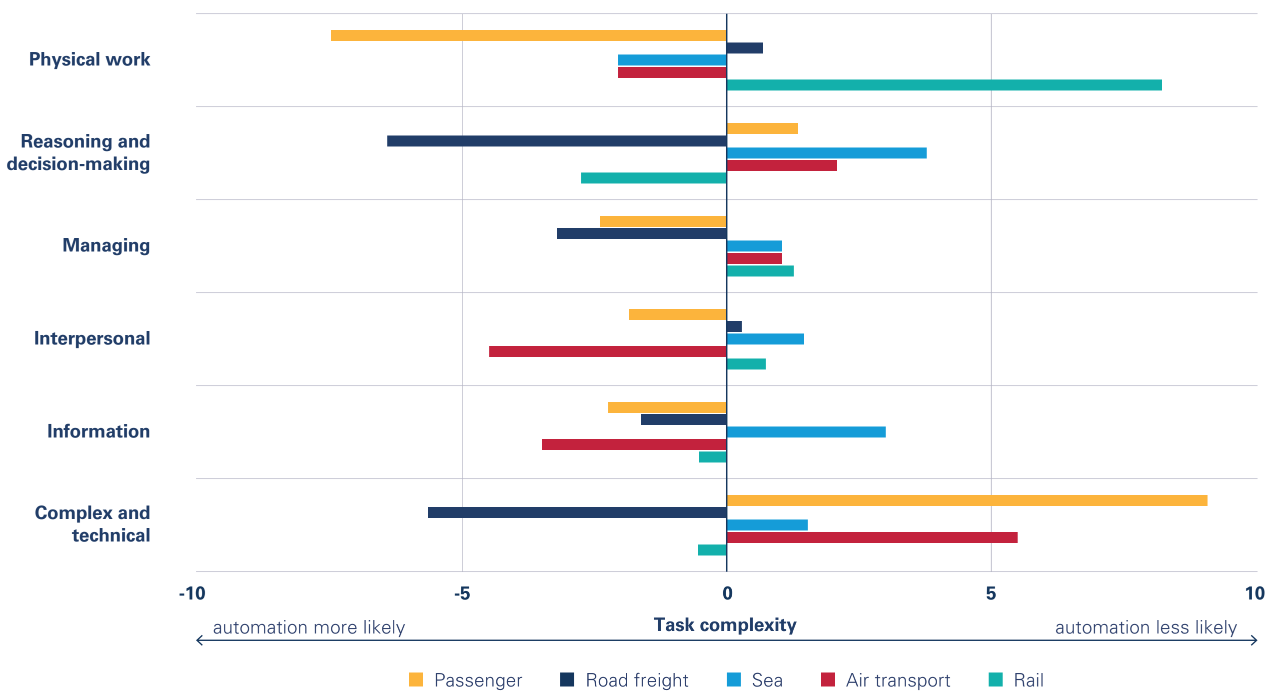
The results show that tasks associated with rail transport are less prone to automation (higher score), while automation is most likely to occur in passenger road transport (lower score). The potential for deep-sea transport is similar to that found in air transport. Task profiles are more diverse within the supporting activities of a specific transport mode, such as cargo handling in ports or airports. Supporting activities for road freight and deep-sea transport have the greatest potential for further task automation (lower score), while further automation is more difficult to be achieved in the supporting activities for rail transport (higher score). The variance found across tasks indicates that automation will take place in some industries earlier than in others, even when technical feasibility is the only factor considered, i.e. from the standpoint of using current or foreseeable technologies to automate tasks.

TABLE 3.2 Automation technical bottlenecks are similar across sectors

	Perception and Manipulation	Creative Intelligence	Social Intelligence
Land	2.4	1.7	2.4
Sea	2.6	1.8	2.6
Air	2.6	1.9	2.7
Support	2.4	1.7	2.4
Economy	2.4	1.7	2.4

Sources: O*Net, U.S. Bureau of Labour Statistics (2016 employment data), WMU analysis

FIGURE 3.7 Industries relying more on low complex physical work and information input and processing are more prone to automation



Sources: O*Net, U.S. Bureau of Labour Statistics (2016 employment data), WMU analysis

5 TRENDS IN LABOUR DEMAND

The further introduction of automation and computerization in the transport sector, as this report concluded in its previous sections, is expected to occur in the coming decades. Based on the projections of technological development, the report has shown that a high potential for task automation exists. From a technical standpoint, transport sector tasks have a high probability of task automation and computerization, like the rest of the economy, especially in low- and middle-skilled jobs. However, a high degree of automation can be a potential scenario for the future of work. Other interconnected factors can determine the extent and pace of its introduction.

Building the start-up curves estimated in Chapter 1, the report made an estimate of how much impact on labour is foreseen by 2040. Contrary to the estimates presented previously, the start-up curves integrate the factors that influence technology.[31] Based on the estimates obtained, and assuming a constant product demand, an estimation was made of the impact of novel technologies on jobs. It is important to note that by considering a constant product demand, the simulations undertaken are not capturing the general equilibrium effects on employment.

Recent studies have shown that job elimination due to automation of routine tasks has been overcompensated by job creation attributed to increasing product demand. Therefore, while interpreting the results obtained, a downward bias needs to be considered when analysing the results. In regard to the demand for seafarers, in our analyses we have incorporated an effect driven by increasing international trade. The effects of increasing trade are introduced to mitigate this bias into the simulations, in a second stage.

Experts calibrated the models. Due to the extended time frame considered i.e. 20 years, the estimates have a high degree of uncertainty. Although quantification of the uncertainty was included in the simulations, potential disruptive shocks, such as substantial changes in trade, wars, or unexpected technologies, were not considered. Nevertheless, the results of the simulations provide a quantifiable assessment of the foreseen impact of technology on labour markets by 2040. They form the basis for the development of policy recommendations that can ameliorate possible socio-economic imbalances arising from technological change.

[31] Assessing the importance of each factor individually in the overall effect is out of the scope of this study.

5.1 SIMULATIONS

To model the effects of technology diffusion on labour, the report established current technology as the baseline. The baseline, therefore, represents manning levels in current technology. The manning indices were simulated separately for low- and middle-skilled workers, on the one hand, and high-skilled workers, on the other, as technology is expected to affect these two groups differently. The model further assumes that technology will lead to a decrease in labour demand for the same output level and that the decline follows a gradual process. Therefore, the results presented do not account for changes to the output level (demand for transport).

The modelling of technological progress takes as a given that, as technology becomes more mature, the potential for labour saving increases in comparison to the baseline. The penetration rate estimated through the start-up curves determines the mix between novel technologies and vintage technologies (baseline). The several factors that affect the introduction and diffusion of technology are rendered endogenous in the first stage start-up curves estimations, and it is not possible to disaggregate them in the simulation model used. Therefore, the results presented consider the six factors that affect technological change, but a further assessment of the mechanisms and policies that can shape technological change is needed.

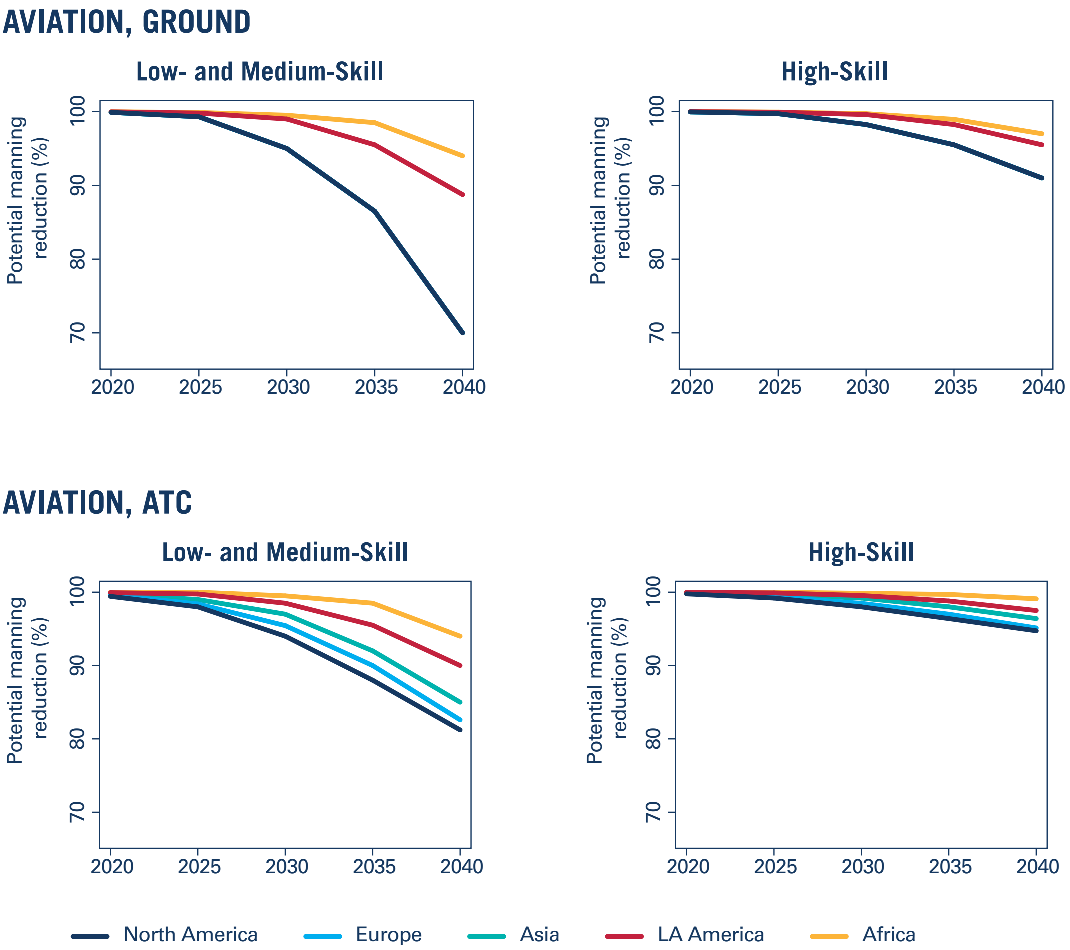
5.2 AVIATION

The simulation for aviation focuses on two sections of the value chain, where the impact of new technologies is expected to be significant: 1. airport ground services (autonomous vehicles and airport automation); and 2. airport and traffic control (smart airports and NextGen systems).

The results for ground services for both skill groups (Figure 3.8) confirm that labour groups from different regions will experience the technological process differently. The innovations coming to ground services are expected to impact Asia, Europe and North America at a similar pace, a fact that translates into a similar potential labour reduction. For these regions, tasks currently accomplished by ten people will be executed by approximately seven workers in 2040. Three in every ten jobs are expected to be eliminated; however, the international trade trends described in Chapter 2 can offset this result.

The increasing demand for transport also raises the demand for labour, resulting in job creation, counterbalancing the technology-driven job elimination. In other regions, like Africa and Latin America, the effects on labour are less pronounced as the adoption of technology will take longer. The research undertaken estimates that less than 12 per cent of the jobs will be eliminated, a number that is easily offset by job creation driven by the demand for transport. A similar percentage is found for the high-skill group, where the demand for labour is estimated to decline between 3 and 9 per cent by 2040, depending on the automation schedule of the region.

FIGURE 3.8 Simulation for labour reduction – aviation (ground and ATC)



Notes: Europe, North America and Asia have similar estimations, hence the curve overlap. The estimated subjective uncertainty of the mean for 2040 is, on average, between 7 and 10 per cent.

5.3 ROAD

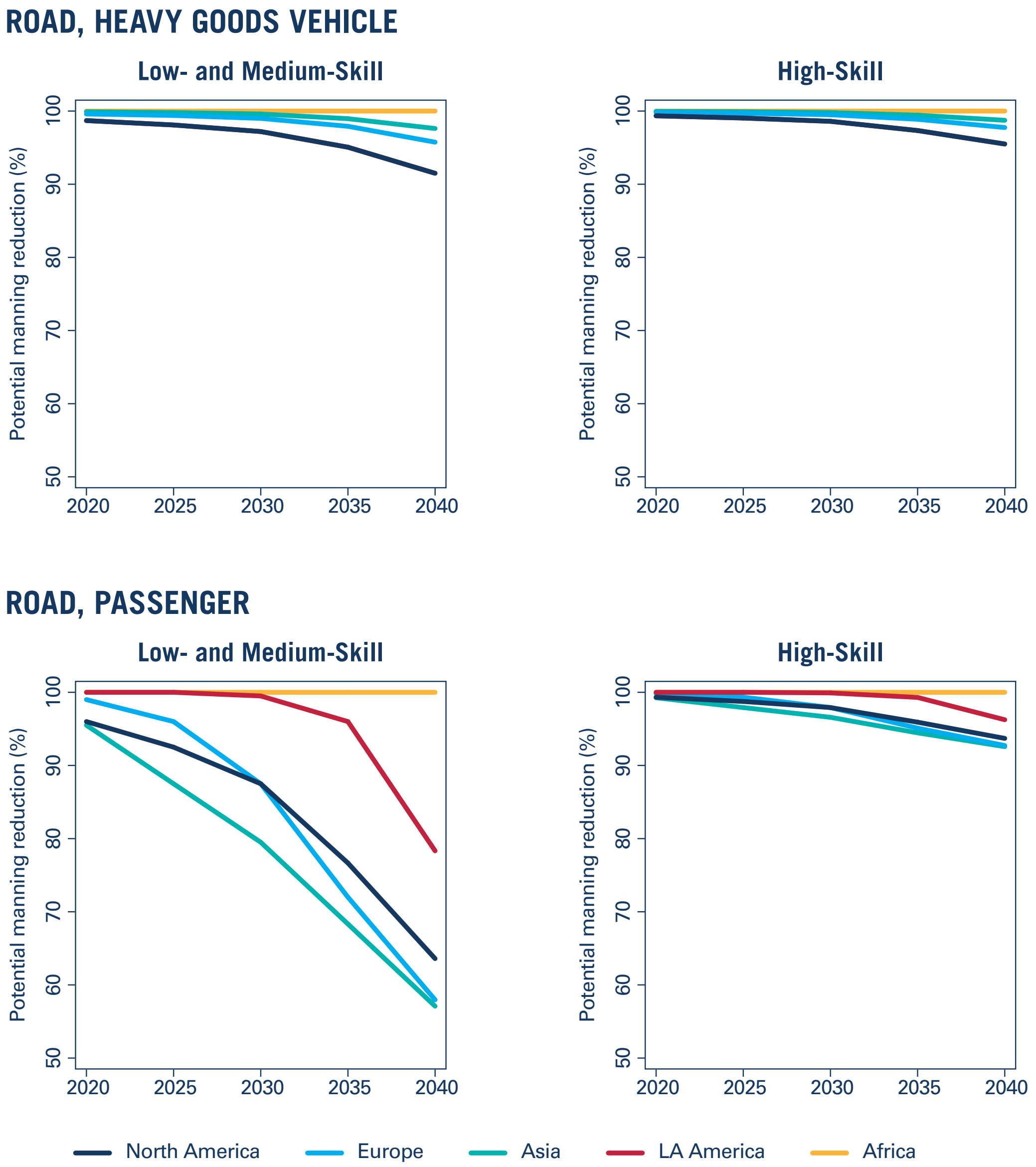
The simulations for road transport are performed separately for heavy goods vehicles (HGV) and passenger road transport (buses, mini-buses and taxis). The two are very different, and the effects of automation are expected to be felt differently. Both are summarized on Figure 3.9.

For HGV, our simulations do not show a significant decrease in today's share of labour. At most, the low and medium skill groups are expected to decrease by approximately nine percentage points. Even though a decline is expected, one should note that the simulations assume a constant product demand (as it exists today). As highlighted in the previous chapter, the report forecasts a positive outlook for road transport. Thus, increasing road transport, which positively impacts on labour demand, is most likely to offset any identified declines in labour demand.

Conversely, our simulations indicate a different picture for passenger transport. For Asia, Europe and North America, the low- and middle-skilled workforce required to transport the current number of passengers is estimated to be approximately half of what it is today. This number is less pronounced for Latin America, where our simulations point to a decline of 26 percentage points. For the high-skill group, our simulations do not forecast a drop exceeding 10 per cent.

For African countries, our models do not point toward any sizable effects of vehicle automation and autonomy (HGV and passenger) on labour demand.

FIGURE 3.9 Simulation for labour reduction – road (HGV and passenger)



Notes: The estimated subjective uncertainty of the mean for 2040 is, on average, 3 per cent for HGV and 7 per cent for passenger vehicles.

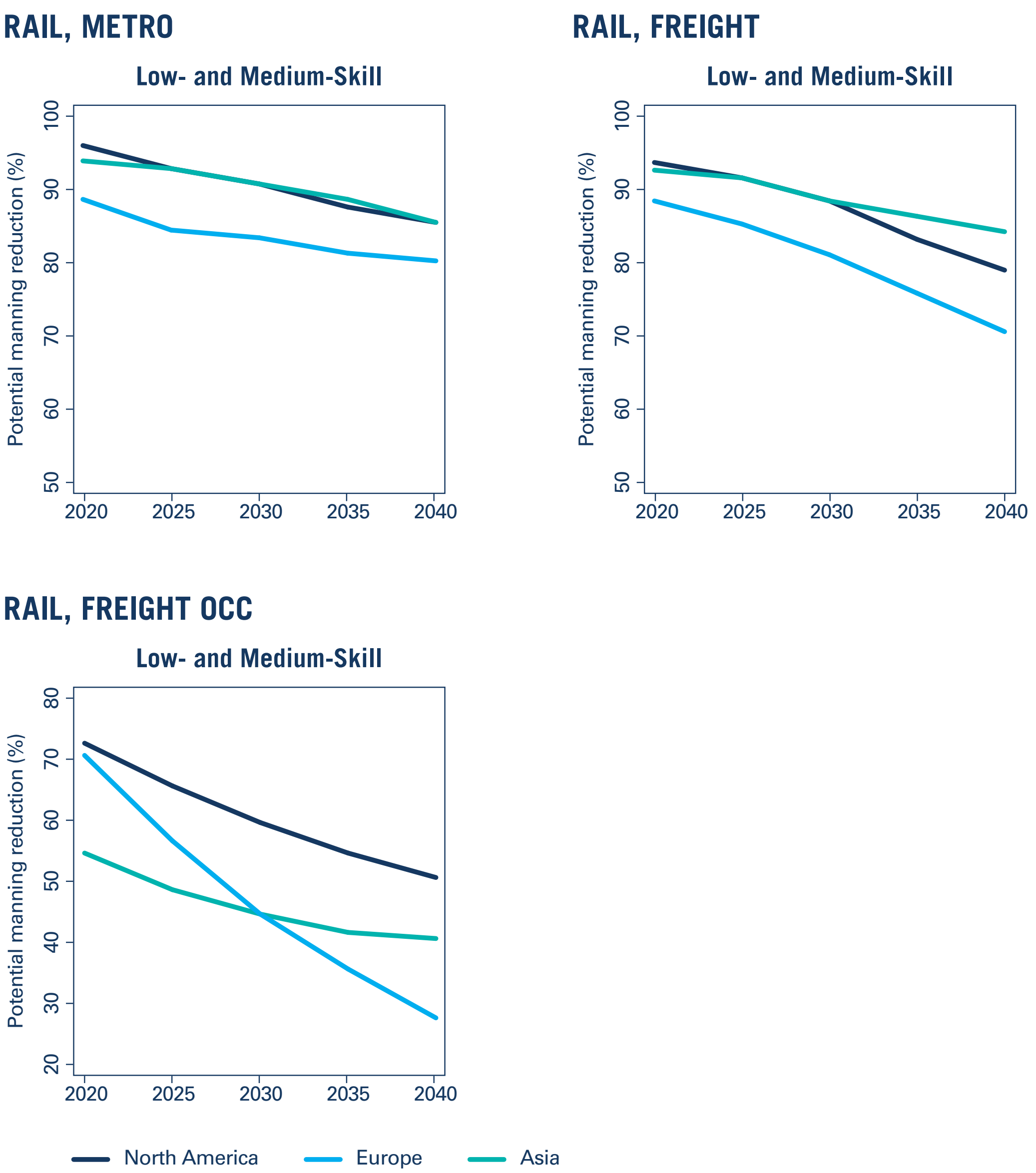
5.4 RAIL

For rail, the simulations are performed for three district categories. The first is fully automatic and unattended metros operating (GoA4) with remote control for disturbances. The second is freight trains, which we subcategorize into: a) fully automatic freight trains (GoA4) with remote control for disturbances; b) Operations Control Centres (OCC) with fully automatic command, route setting (IXL) and signalling (TCS) in normal situations under human supervision and human interaction in disturbances. Given the labour mix, no distinction is made between skill levels and a single labour index is used. Estimates for Africa and Latin America are not included as the estimates have high levels of uncertainty of approximately 50 per cent and its presentation can lead to misleading interpretations.

The results from the estimations are plotted in Figure 3.10. The labour indexes for Europe, Asia and North America show similar downward trends, but with different magnitudes. The labour decline is estimated to between 15 per cent to 20 per cent by 2040, with Europe leading the decline. The labour index for train freight shows a similar scenario, a faster decline for Europe (about 29 per cent by 2040) followed by North America (21 per cent) and Asia (16 per cent).

Similar results are found for the train Operations Control Centres (OCC) whereby by 2040 a decline of 72 per cent is expected for Europe, 49 per cent for North America and 41 per cent for Asia. It is worth noting that the estimates are subject to uncertainty, which the report quantifies at between 2 and 8 per cent. Furthermore, the estimates reflect only a decline due to technology implementation, that is, they do not take the growing demand for transport into account, as forecast in Chapter 2. Such an expansion of demand has the potential to outweigh and further increase the current labour demand.

FIGURE 3.10 Simulation for labour reduction – rail (metro, freight, freight OCC)



Notes: The estimated subjective uncertainty of the mean for 2040 is on average 1 per cent for metros, 2 per cent for freight train, and 8 per cent for freight OCC.

5.5 MARITIME - SEAFARERS

The simulations undertaken to assess the demand for seafarers used a different methodology and assumptions than the simulations for the other transport modes. For seafarers, the assumption of a constant demand for transport was dropped, and instead it was based on the premise that the demand for maritime transport would continue to follow its historical trends. Thus, the simulated demand for seafarers reflects market trends, and provides an estimate of the global demand for seafarers. The report opted not to focus on different regions since demand for this category of workers is usually considered to be global.

The source for the historical data on measuring demand used to generate a baseline model is ICS/BIMCO (2016). As in the other simulations, these consider the evolution of technology measured by the start-up curves of Chapter 1. The modelled curves encapsulate both expectations for technological progress in shipping, and the external factors affecting its deployment and large-scale use (see Infobox 3.E). The crewing assumptions take into account the expected crew reduction associated with the introduction of highly automated ships.[32]

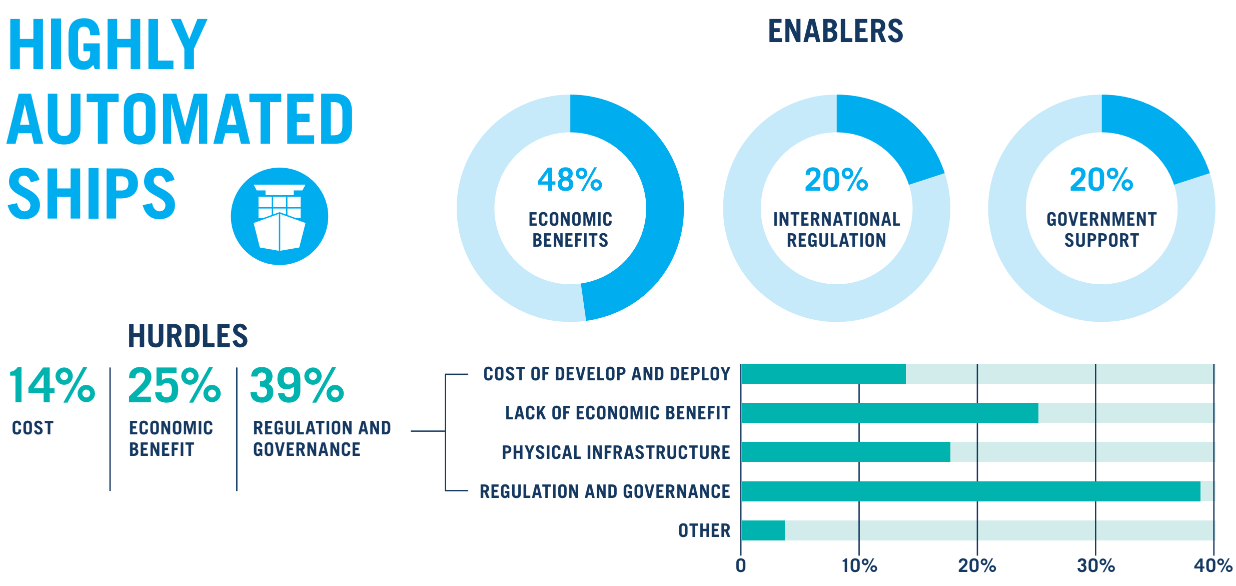
The simulations undertaken consider two scenarios. In the first, demand follows its historical pattern; and in the second, expected trade growth is the same as forecasted in Chapter 2. The results are plotted in Figure 11 and show that the introduction of highly automated ships will lead to a decrease in the global demand for seafarers by 2040 vis-à-vis the baseline projection based on current technology. In comparison to the present, demand will continue to grow. The absolute number of seafarers is not expected to decrease by 2040. However, the growth rate is expected to attenuate as a consequence of the introduction of autonomous ships.

The simulations show that the introduction of highly automated ships decreases the growth rate in the demand for seafarers, leading to a potential reduction of 22 per cent (Figure 3.11, dashed line) in global demand for this category in comparison to the projected demand baseline (conventional ships). Similar effects are observed for both officers and ratings. When accounting for the increase in the volume of seaborne trade projected for 2040 as forecast in Chapter 2, the simulations show that its effects do not compensate for the overall reduction of labour demand (see Figure 3.12). Trade is expected to hamper the impact of automation on the demand for seafarers by 36 per cent (Figure 3.12, dashed line).

Despite the decline in the growth rate, it is important to note that, for the period under analysis, all our simulations point towards growth in the demand for seafarers from 2020 to 2040. In absolute numbers, the number of seafarers required by 2040 is expected to be significantly higher than its current level. In some scenarios, the figure is almost double than the approximately 1.6 million seafarers working today.

However, what technology is expected to do is to slow down the increase in the number of seafarers needed to carry out global trade.[33]

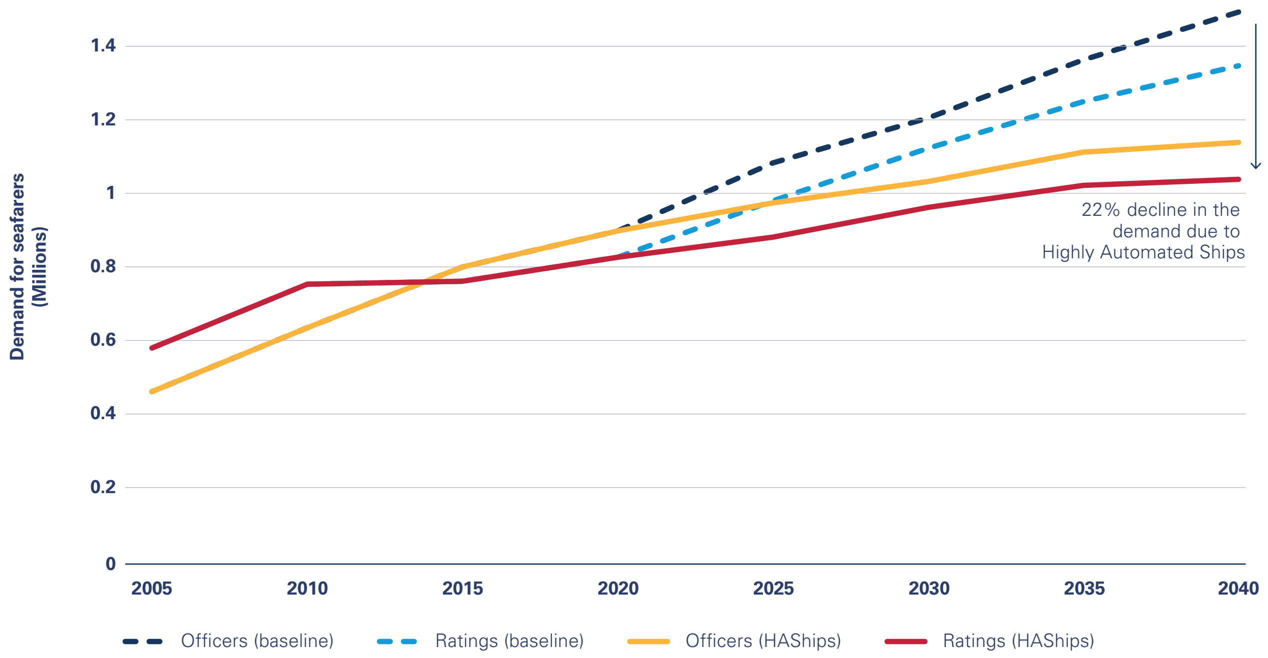
INFOBOX 3.E WHAT FACTORS CAN ENABLE OR DELAY HIGHLY AUTONOMOUS SHIP DEPLOYMENT?



[32] The estimations are based on the start-up curves shown previously. The data comes from expert inquiries during the IMO SSE5 and United Nations Economic Commission for Europe (UNECE) SC.3/WP.3 workshop on "Autonomous shipping and inland navigation" (2018). We based our manning assumptions on estimates collected through interviews with shipping technology specialists. The baseline (conventional ships) is econometrically modelled using ICS/BIMCO data (see, ICS/BIMCO (2016) for more details) and United Nations Conference of Trade and Development (UNCTAD) data. Please note that the International Labour Organization Maritime Labour Convention, 2006, as amended, Article II (f) defines a seafarer as "any person who is employed or engaged or works in any capacity on board a ship". While the simulations undertaken cover most seafarers, some are not considered. The merchant seafarers considered in the analysis are those also considered by the ICS/BIMCO (2006) report.

[33] The simulations undertaken are a result of expert judgment on technology. The experts consulted were part of the IMO SSE5 and UNECE SC.3/WP.3 workshop on "Autonomous shipping and inland navigation". The estimates are subject to a high-level of uncertainty due to its long time frame. The simulations do not consider any shocks in product market demand or consumption spillover effects. Such effects can dictate the degree of impact on labour demand.

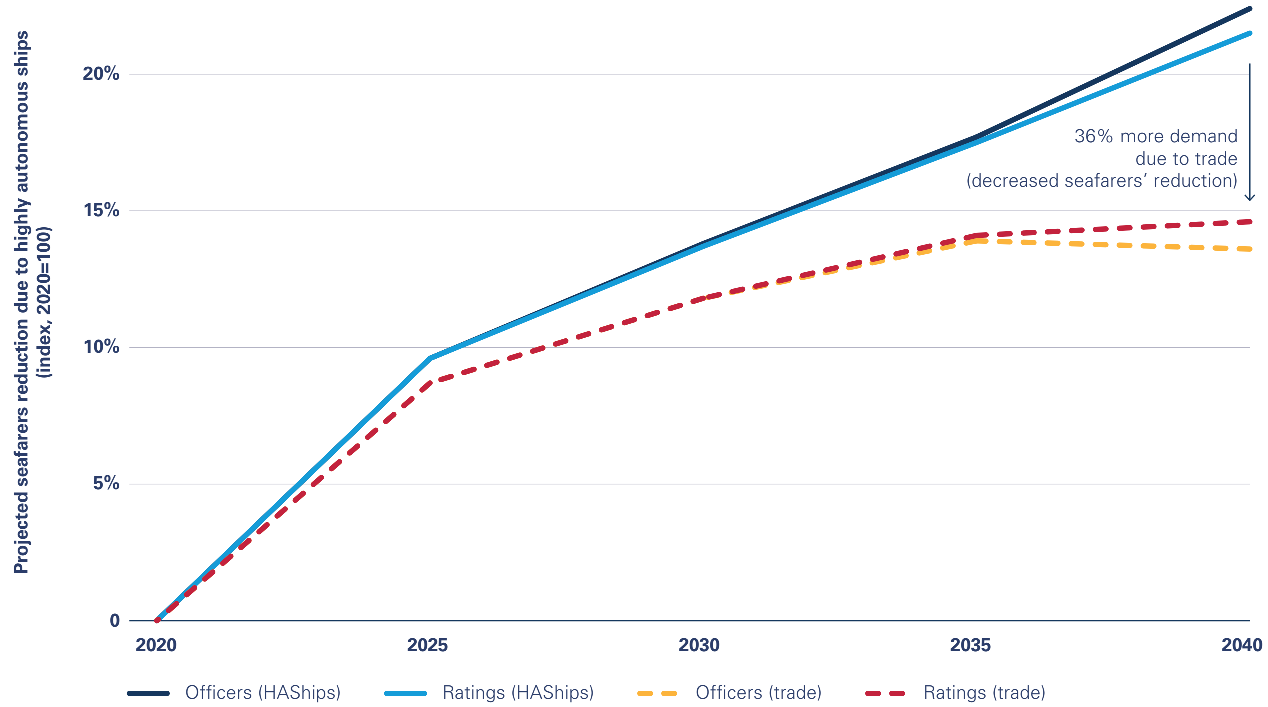
FIGURE 3.11 Simulations for the demand for seafarers



Sources: Historical data from ICS/BIMCO (2016); forecast used data from the start-up curves of Chapter 1 and UNCTAD maritime data; WMU forecast.

Notes: HAShips stands for Highly Automated Ships taking international voyages (average tonnage, average trade). The predictions are subject to a high level of uncertainly, quantified between -6 percentage points and +18 percentage points within a 95 per cent confidence interval. The crew reduction approximately follows an exponential process and by 2040 the crewing levels are assumed to be reduced between 16 and 24 per cent.

FIGURE 3.12 Projected reduction on the labour demand for seafarers



Sources: historical data from ICS/BIMCO (2016); forecast used data from the start-up curves of Chapter 1 and UNCTAD maritime data.

Note: The graph displays a reduction in the demand for seafarers in comparison with the baseline (conventional ships, that is, no Highly Automated Ships, HAShips). A decrease in the graph corresponds to an increase in the demand for seafarers.

FINAL REMARKS

To sum up, Chapter 3 looked at the effects of automation on employment and skills. In particular the analysis highlighted the potential of technological innovation/automation and the way it impacts different skills groups in the maritime transport sector in different ways. The impact is not monolithic because the analysis found that, side by side with displacement and elimination, the growing use of technologies in the workplace can lead to more job creation.

In Chapter 4 Maritime Technology Profiles, by using five indicators in the analysis, the report measures a country's preparedness for adopting emerging and new technologies, in particular automation. A total of 17 countries from four different economic groups give a profile of a country's readiness to embrace automation and technology focusing on the maritime transport.

CHAPTER 4

COUNTRY PROFILES

4

SUMMARY

The maritime technology country profiles are designed to give an overview of the position of countries with regard to the new and emerging technologies by highlighting five factors that measure a country's readiness for automation by 2040. A country's profile can be considered to be an indicator for measuring both current national readiness to use emerging and new technologies and as a reference point for future strategic actions. The five primary indicators used are: 1. Innovation and Technology; 2. Infrastructure Quality; 3. Regulation and Governance; 4. Human Capital and Skills; and 5. Business and Investment.

This chapter is divided into three main sections: 1. Measuring readiness for the adoption of new and emerging technologies; 2. Technical notes and sources (Appendix D); and 3. Detailed country profiles (at the end of this report). The section on measuring readiness for the adoption of new and emerging technologies provides the methodology and framework relating to the country profiles. The profiles section provides a snapshot of a country's readiness. Technical notes containing details of how the five indicators were measured can be found in the final section of the report.

A review of developments across all country profiles yields three key findings:

1. **New and emerging technologies will be implemented in varying degrees in different regions in the world**
2. **A clear gap exists between developed and developing countries[34] in the maritime sector**
3. **Most countries have not developed long-term plans for automation in the maritime sector**

1 INTRODUCTION

The world is at the beginning of a global transformation as a result of the Fourth Industrial Revolution (4IR or Industry 4.0). Stakeholders from public and private sectors are confronted with new challenges and uncertainties regarding developments in the global transport industry. In earlier chapters of this report, an overview was presented concerning technological developments and their potential impact on labour. This chapter includes a discussion on different future transport scenarios. These developments will also be influenced by local factors. For example, trade patterns will differ as a result of economic growth in different parts of the world. Similarly, the effectiveness of regulations will depend on the legal frameworks in place in different jurisdictions.

INFOBOX 4.A 4TH INDUSTRIAL REVOLUTION

The **Fourth Industrial Revolution (4IR)** is the fourth major industrial era since the first Industrial Revolution, which began in the 18th century. The 4IR is ascribed to the combination of technologies stemming from the physical, digital and biological spheres. It encompasses a number of fields such as robotics, artificial intelligence, blockchain, nanotechnology, the Internet of Things, 3D printing and autonomous vehicles (Klaus Schwab, 2016).

[34] The classification of developing and developed countries is taken from the World Bank, which divides economies into four income categories based on gross national income per capita (in current U.S. dollars): high income, upper-middle income, lower-middle income and low income.

In this context, the presentation of country profiles aims to give a comparative snapshot of a country's readiness regarding automation and technology, with a focus on the maritime transport sector, thereby enabling cross-country-regional comparisons. Readiness can be defined as "the capability to capitalize on the future, mitigate risks and challenges, and be resilient and agile in responding to unknown future shocks" (World Economic Forum / A.T. Kearney, 2018). The premise for this approach is as follows: due to new technologies, the changing nature of the maritime transport sector requires new frameworks to increase understanding of the factors that can help in a consistent and optimal shaping of national maritime transport systems as they undergo transformation in a globalized world.

The maritime technology country profiles are based on statistical information and conclusions drawn from interviews with key informants/experts in the maritime transport sector - both in industry and academia.[35] The profiles were designed to create a reliable framework to assess the preparedness of countries in the adoption of new technologies in the maritime field.

The country profiles are composed of a wide-range of internationally comparable factors identified as critical to the transformation of the maritime transport sector, allowing users to assess and compare countries and to gauge the pace of change related to new technologies. In that regard, five key factors are analysed.

Under each indicator, a number of sub-indicators are measured. In each case, a discussion is undertaken to provide an analysis of the ability, potential and likelihood of a country adopting new and emerging technologies across all industry sectors. This study considers the maritime transport sector as an example to measure the readiness of countries for the introducting of technology and automation.

INFOBOX 4.B WHAT IS AN INDEX?

In the context of this report, an **index** is the combination of several indicators for measuring a country's readiness to adopt new and emerging technologies in the maritime sector.

The WMU team has used quantitative and qualitative research data to measure the readiness of countries for current and future transformations in the maritime field. In this respect, the country profiles provide a basic understanding of a country's current readiness to adopt different future scenarios.

For both the general and maritime technology profiles, continuous testing of the connection and the understanding of causal links among the indicators and the use of new technologies will help further validate the framework and identify differences across countries and regions.

The following 17 countries[36], representing five regions in the world, have been used as a basis for this analysis:[37]

- Africa: Ghana, Nigeria and South Africa
- Americas: Brazil, Panama, Peru and the United States of America
- East Asia and the Pacific: Australia, China, Japan, Philippines and the Republic of Korea
- Europe: Denmark, France, Norway and Sweden
- Middle East: Turkey

[35] The country profiles are based on statistical and quantitative data reported from national and regional agencies to international organizations such as the World Bank, the OECD, the United Nations Industrial Development Organisation (UNIDO), UNCTAD and the IMO – especially from the maritime country profile data-base, the ILO, think-tanks and international research and statistical institutions. To develop the five factors, the following approaches were used: 1. Comprehensive and intensive literature review to arrive at the factors chosen for the country profiles; 2. Workshops with Canadian, Japanese and French delegations; 3. An online interactive tool and a panel discussion with 13 participants carried out during the Shipping Conference 2030 in New York; and 4. Further consultations with academic experts, stakeholders and industry experts through one-to-one interviews and participations in conferences.

[36] The countries were selected based on the need to identify representative countries in a region. The data used in this report do not include data from Taiwan (Province of China), and Hong Kong (China).

[37] The regions and countries are classified in alphabetic order. Please see Table D.1 in Appendix D.

2 COUNTRY PROFILES AS A TOOL TO DETERMINE FUTURE STRATEGIES

The country profiles have three main objectives to: 1. Measuring the readiness of countries to introduce new technologies in the maritime field; 2. Providing a mechanism for stakeholders to disseminate country-and-region specific policy analyses related to technological transformation and help with agenda-setting (UNECA, 2013); and 3. Setting up a standardized framework for measuring readiness using different scenarios of the future of maritime transport that can be used to benchmark countries other than those selected for this report.

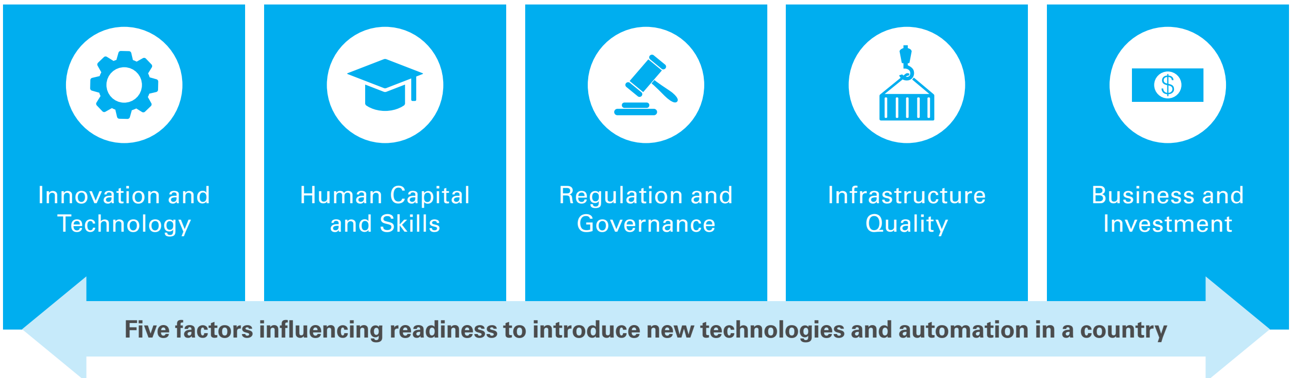
1. With respect to objective one, the country profile results can provide an overview of a country's ability to introduce new and emerging technologies, particularly in the maritime sector.

2. Concerning objective two, stakeholders working in the maritime sector will need to determine the best way forward in confronting a new era of automation and technology. This new reality will inevitably challenge the current state of the maritime labour market. In order to appropriately address and respond, the maritime leadership must recognize the importance of being proactive in managing the effects of emerging technologies should they be implemented. Equally important is the need for a clear comprehension of countries' current preparedness levels in guiding future planning initiatives. In that regard, the country profiles aim to provide a "medium"/channel through which appropriate policy action could be taken by a country and/or region for the future. An assessment of the country profiles would be necessary, as well as a framework to help identify the main levers of policy that would enable the future transformation of the maritime transport sector.

3. Concerning objective three - establishing a standardized framework for measuring readiness of countries - it is clear that economic, social, and political contexts and regulatory systems vary. Country profiles would, therefore, provide a clear framework that can be used by all countries taking into account their differences. They aim to create a framework that can be used for a global assessment of the future of maritime transport.

As mentioned earlier, the concept of the country profiles is based on five key factors: 1. Innovation and Technology; 2. Human Capital and Skills; 3. Regulation and Governance; 4. Infrastructure Quality; and 5. Business and Investment (see Figure 4.1).

FIGURE 4.1 Key factors influencing the introduction of new and emerging technologies in a country



INFOBOX 4.C WHAT ARE PERFORMANCE FACTORS?

In general, a factor or indicator is a quantitative or a qualitative measure resulting from a series of factors that can reveal relative positions (e.g. of a country) in a specific area.

In this study, we consider factors as a measurement of performance. The performance factors should be used in combination with each other to cover all facets of an activity, product or service (Fortuin, 1988). Factors are not considered as a goal per se, but as a variable, or a pattern or variables, selected to characterize or define a subject or phenomenon (Gudmundsson et al., 2016). In that regard, performance factors are formed when individual indicators are compiled into a single index on the basis of an underlying model.

Performance factors are critical to any organization as they help provide information and evidence to support strategic decision-making. They are useful in setting policy priorities and in benchmarking or monitoring performance related to an issue or phenomenon. They should also ideally measure multidimensional concepts that cannot be captured by a single factor, e.g competitiveness, industrialization, sustainability, among others (OECD, 2008). The main pros and cons of using performance indicators (see Table 4.C) were adapted by the OECD (2018) from Saisana and Tarantola (2002).

TABLE 4.C Pros and cons of country performance indicators

PROS AND CONS OF PERFORMANCE INDICATORS (PIs)

PROS	CONS
• PIs can summarize complex, multidimensional realities with a view to supporting decision-makers. • PIs are easier to interpret than a battery of many separate indicators. • PIs can assess progress of countries over time. • They can reduce the visible size of a set of indicators without dropping the underlying information base. • The can facilitate exchange with key-actors	• PIs may send misleading policy messages if poorly constructed or misinterpreted. • PIs may invite simplistic policy conclusions. • PIs may be misused, e.g. to support a desired policy, if the construction process is not transparent and/ or lacks sound statistical or conceptual principles. • The selection of indicators and weights could be the subject of political dispute. • They may generate serious failings in some dimensions and increase the difficulty of identifying proper remedial action, if construction process is not transparent. • Inappropriate policies may arise if dimensions of performance that are difficult to measure are ignored.

Source: OECD (2008)

2.1 INNOVATION AND TECHNOLOGY

Innovation and technology has been identified as the main driver in the transformation of the maritime transport sector. Innovation and technology identify the conditions that permit different actors working in the maritime sector to innovate and embrace new technologies. Therefore, this realm shows to what extent a country has advanced in secure and connected information and communication technology (ICT) infrastructure to support the development and adoption of new technologies in maritime transport.

It is also related to a country's ability to foster and commercialize innovations that have potential applications in maritime transport. Based on the Global Innovation Index (Cornell University et al., 2017), innovation and technology can be measured at a country level for example, by assessing investment in new technologies, research intensity, industrial activity and availability and usage of ICT. In developing the maritime transport technology index, other measures considered are the export of ships as a share of total exports, the average age of a fleet and maritime/marine engineering universities (Figure 4.2).

FIGURE 4.2 Concepts captured for the measurement of innovation and technology factor (Factor 1)

FACTOR 1: INNOVATION AND TECHNOLOGY	
Measures for the General Profile	• Technology platform • Ability to innovate
Measures for the Maritime Profile	• Export of ships as share of total exports • Average age of fleet • Maritime/marine engineering universities

2.2 HUMAN CAPITAL AND SKILLS

According to the OECD, human capital is defined as "the knowledge, skills, competencies and other attributes embodied in individuals or groups of individuals acquired during their life and used to produce goods, services or ideas in market circumstances" (OECD, 2001). In this report, the level of human capital and skills shows a country's ability to respond to shifts in maritime transport triggered by the 4IR in respect of current workforce capabilities and its long-term ability to cultivate the right skills and talent for a future maritime workforce (see Figure 4.3).

Different approaches are used to measure human capital and skills. According to the UNECE Guide on Measuring Human Capital, human capital and skills in the field of innovation and technology could be measured by indicators such as education outcomes, availability of scientists and engineers, digital skills among the population and labour force capability (UNECE, 2016). In the maritime technology field, it could be measured by the ratio of officers to total seafarers and by the total number of seafarers.

FIGURE 4.3 Concepts captured for the measurement of human capital and skills factor (Factor 2)

FACTOR 2: HUMAN CAPITAL AND SKILLS	
Measures for the General Profile	• Labour force capability • Education outcomes • Knowledge
Measures for the Maritime Profile	• Ratio of officers to total seafarers • Total number of seafarers

2.3 REGULATION AND GOVERNANCE

Regulation and governance (Figure 4.4) can either encourage technology adoption/development or be an impediment to such adoption/development. How Governments enact and implement regulations will have a drastic impact on the private sector's willingness and ability to adopt and/or develop new and emerging technologies. As with all market sectors, laws and/or regulations can drastically impact financial decisions and create legal barriers which dramatically influence the behaviour of business. Thus, in the general profile, this factor seeks to assess the rule of law[38] in a country, regulatory efficiency, incidence of corruption and the future directions that Governments may adopt in that regard. Regarding the maritime profile, this realm seeks to assess how active a country is in discussions about maritime autonomous surface ships at the IMO, in the ratification of IMO Conventions and in its engagement of IACS and non-IACS classification societies.

FIGURE 4.4 Concepts captured for the measurement of regulation and governance factor (Factor 3)

FACTOR 3: REGULATION AND GOVERNANCE	
Measures for the General Profile	• Rule of law • Regulatory efficiency • Incidences of corruption • Future orientation of Government
Measures for the Maritime Profile	• Contribution to discussion about maritime autonomous surface ships at the IMO • Ratification of IMO Conventions • IACS and Non-IACS classes

2.4 INFRASTRUCTURE QUALITY

Efficient infrastructure is critical in order to foster economic growth. Economies depend on high quality modes of transport, high-quality roads, railway transport systems, ports and airports, all of which enable the delivery of goods and services to customers in a safe, secure and timely manner and simplify movement of the workforce. Economies also depend on the quality of energy/power sources/supplies which enable businesses and factories to function without interruption (Schwab, 2017). Economic growth is also linked to the performance of telecommunication networks which allow for rapid, secure and free exchange of information. Thus, the infrastructure quality indicator assesses a country's ability to have a sufficiently high-quality infrastructure to support new and emerging technology vehicles (Figure 4.5). In general, this can be measured by the waiting time to obtain selected utility services and the time of disruption of these services (Schwab, 2017). In the case of maritime transport, specifically two measures were captured within our research: quality of ports and liner shipping connectivity.

FIGURE 4.5 Concepts captured for the measurement of infrastructure quality factor (Factor 4)

FACTOR 4: INFRASTRUCTURE QUALITY	
Measures for the General Profile	• Transport network and superstructure quality • Electricity infrastructure existence and quality • Telecommunication networks coverage and quality
Measures for the Maritime Profile	• Quality of port • Liner shipping connectivity

[38] According to the Online Oxford English Dictionary (accessed on 15 May 2018), the rule of law is the "authority and influence of law in society, especially when viewed as a constraint on individual and institutional behaviour; (hence) the principle whereby all members of a society (including those in Government) are considered equally subject to publicly disclosed legal codes and processes". There are many definitions of the rule of law.

2.5 BUSINESS AND INVESTMENT

In general, the Business and Investment factor (Figure 4.6) aims to assess the country's involvement in international trade to facilitate the exchange of goods, knowledge and technology and to establish global connections. It can be measured by trade (percentage of GDP), trade tariffs, logistics performance and foreign direct investment inflows as a percentage of gross fixed capital. In terms of maritime transport, the concepts captured for this study are container port throughput relative to GDP, the number of ships bought by a country and the merchant fleet by country of beneficial ownership.

FIGURE 4.6 Concepts captured for the measurement of business and investment factor (Factor 5)

FACTOR 5: BUSINESS AND INVESTMENT	
Measures for the General Profile	• Trade to GDP • Trade tariffs • Logistics performance • FDI inflows as a percentage of gross fixed capital formation
Measures for the Maritime Profile	• Container port throughput per GDP • Number of ships bought • Merchant fleet by country of beneficial ownership

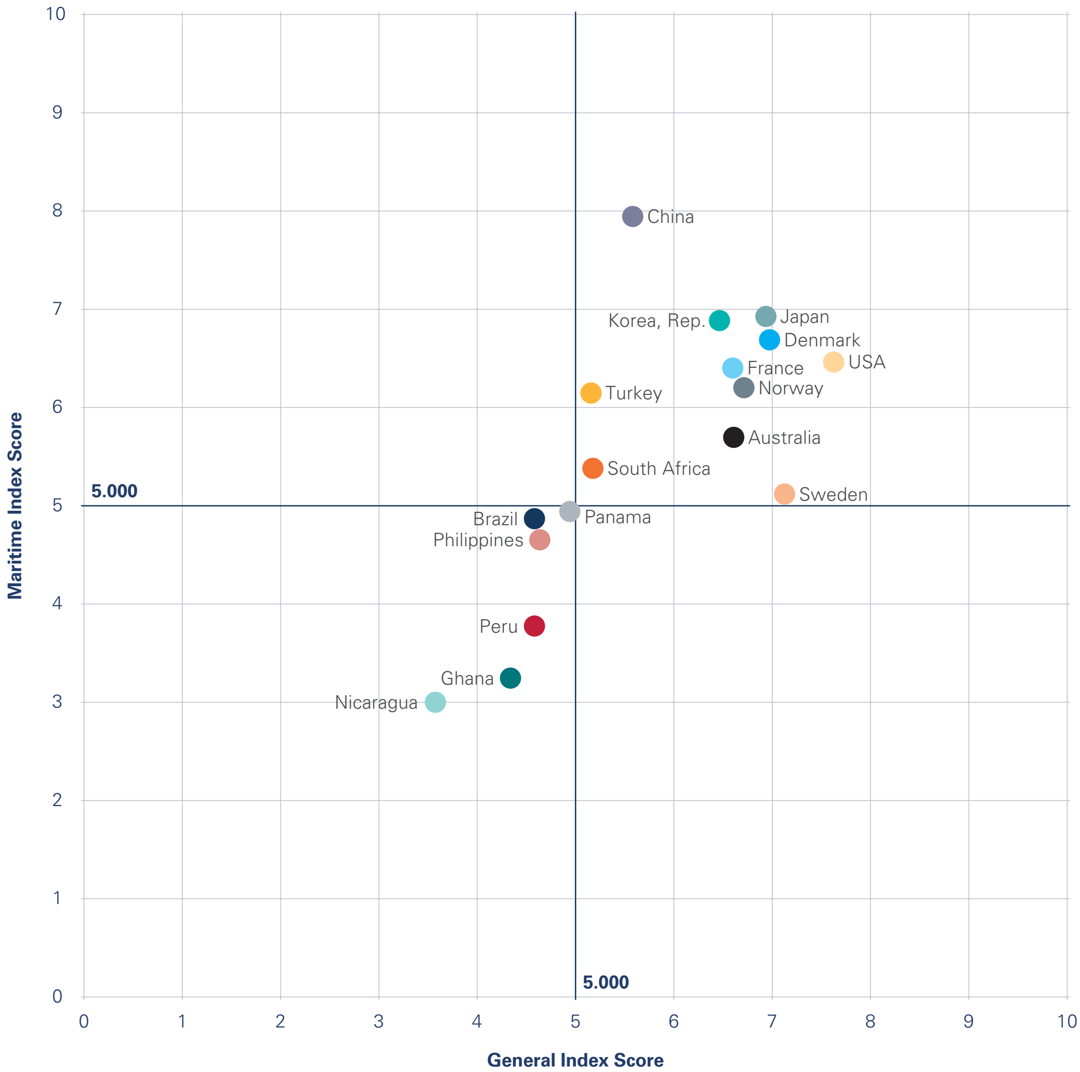
3 FINDINGS

The country profiles assess the readiness of 17 countries and the future transformation of maritime transport by using a scale of 0 for the lowest score to 10 for the highest score based on the five factors. This section examines the overall results and presents and highlights the performance of the 17 selected countries.

3.1 NEW AND EMERGING TECHNOLOGIES WILL BE IMPLEMENTED AT DIFFERENT LEVELS IN DIFFERENT REGIONS OF THE WORLD

As a first overview, the assessment demonstrates that automation will be developed and implemented at differing rates in different regions of the world (see Figure 4.7). In fact, all countries and regions will experience the impact of new technologies but to different degrees depending on numerous factors/variables. Examples of such factors/variables include the quality of infrastructure, the effectiveness of regulation and institutions, the human capital of a country and its political will to invest in new technologies.

FIGURE 4.7 Global map of readiness assessment results for the country profiles

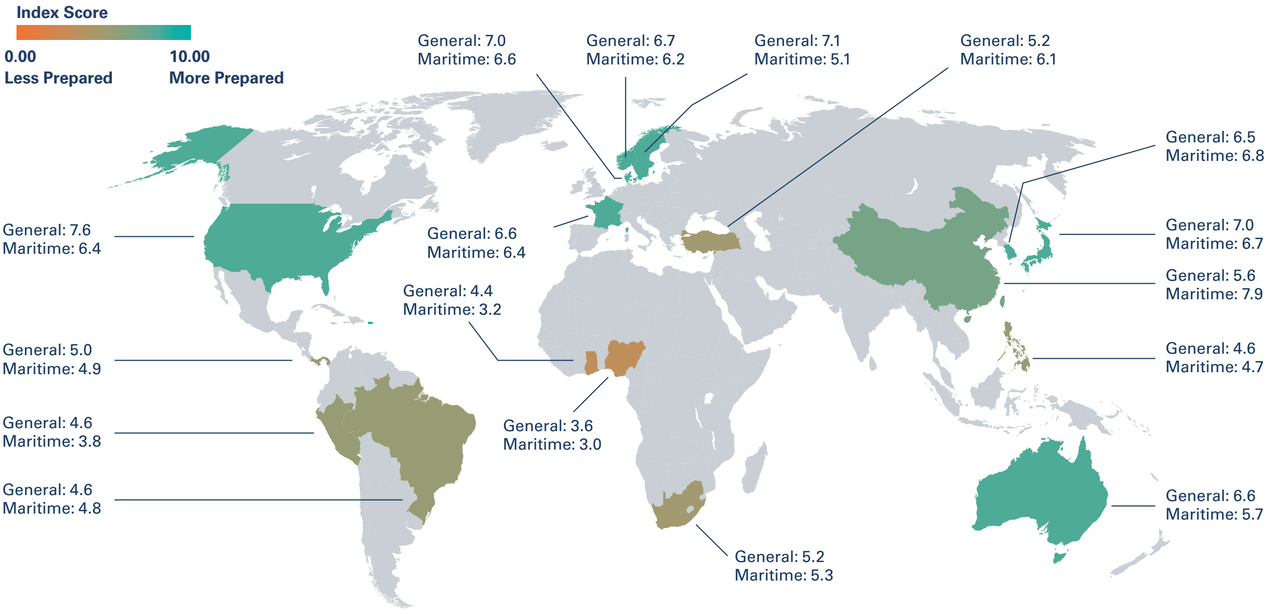


Source: WMU Country Profiles – Technology Readiness: Maritime

As shown in Figure 4.7, countries with a higher readiness to introduce new technologies and automation are located in East Asia and the Pacific, Europe, Australia and the United States. However, countries located in Africa and Latin America are lagging behind in respect of technological advancement, investment, regulation, governance and infrastructure in all economic sectors including maritime transport.

Some countries in the above mentioned list do not currently have adequate infrastructure or relevant business models to enable them to adapt to the new technologies. This could also delay the introduction of automation in different economic sectors, especially the maritime sector (see Figure 4.8).

FIGURE 4.8 Differentiation between countries regarding readiness for emerging and new technologies - general country profiles and maritime country profiles



Source: WMU Country Profiles – Technology Readiness: Maritime

3.2 A CLEAR GAP BETWEEN DEVELOPED AND DEVELOPING COUNTRIES IN THE MARITIME SECTOR

The assessment shows that there is a clear gap between developed and developing countries, especially in the maritime transport sector. The introduction of automation in the maritime field requires significant investment and other inputs, such as infrastructure, effectiveness of regulation and education and training. In that regard, while some countries are seeking to become leaders in the field and building a foundation, from developing technologies to discussing new regulations, other countries will not rapidly introduce emerging and new technologies because of their economic and political contexts. Among the 17 countries in this assessment, nine are leading countries (Australia, China, Denmark, France, Japan, Norway, Republic of Korea, United States and Sweden), while eight are developing or middle-income countries (Brazil, Ghana, Nigeria, Peru, Philippines, Panama, South Africa and Turkey) (see Figure 4.8).

The assessment, therefore, reveals that no country is yet fully prepared to shape the future maritime transport paradigm. In that regard, it is important to note that no leading country has attained a perfect score of 10.

3.2.1 LEADING COUNTRIES' RESULT

As shown in Figure 4.7, the leading archetype consists of nine countries – Australia, China, Denmark, France, Japan, Norway, Republic of Korea, Sweden and the United States. They are bellwether in the development of new technologies, including investment and research and discussions on regulations. Furthermore, some examples of the performance of leading countries are provided as follows (all the scores are on a scale of 0-10 with 10 being the optimal score):

Australia
Based on both the general profile and the maritime profile, Australia is experiencing remarkable development as regards the quality of infrastructure related to new and emerging technologies in general with a score of 8. In the maritime field Australia has a score of 4.09.

In terms of regulations relating to the development of new technologies, Australia is well placed at 7.93. However, in the maritime field, it has a score of 5.35, which is considered to be a good position, given that discussions on the introduction of autonomous ships started late.

In regard to human capital, Australia has a score of 3.75 for its maritime profile and 5.58 for its general profile.

Denmark
Denmark's new technologies sector has evolved considerably, with strong investment in research and infrastructure. The country ranks among the top countries in terms of technology and innovation, with 7.02 in the general profile and 8 in the maritime profile. Denmark is in a good position regarding discussions on the introduction of new technologies in the different economic domains, with 8.44 in general and 6.41 in the maritime sector.

With respect to human capital and skills, Denmark has a good ranking compared to other countries, with 5.15 or the maritime profile and 5.49 for the general profile.

Japan
Japan's new technologies sector is currently in a sound position among the leading countries. It has a general profile of 7.06 for Technology and Innovation and a maritime profile of 9. In terms of regulation and governance, Japan is very active in discussions concerning the development of new technologies, with a score of 7.92 in the general profile and 5.83 in the maritime profile. With respect to human capital and skills, overall Japan performs moderately well with 4.88 for its maritime profile and 5.21 for its general profile.

3.2.2 GOOD POTENTIAL - COUNTRY RESULTS

Figure 4.8 shows that some countries, such as Turkey and South Africa, could be considered emerging economies with respect to technology.

South Africa
As shown in Figure 4.8, South Africa is also considered a high potential country for the adoption of new technologies as it ranks 7.5 for infrastructure related to all economic domains and 4.16 for the maritime profile. For the human capital indicator in the maritime field, South Africa ranks 3.86 and for the general profile 3.46.

Turkey
Based on the research undertaken, Turkey is considered a high potential country as it ranks 8 on technology and innovation for the maritime field and 4.75 for the general profile. In terms of business and investment, Turkey ranks 7.84 for the maritime profile and 4.47 for the general profile. However, with respect to human capital and skills, the country has a lower rank with 3.56 for the maritime profile and 3.63 for the general profile.
4.1.3 Developing countries

3.2.3 DEVELOPING COUNTRIES

As shown in Figure 4.8, the developing countries group consists of six countries from different regions, excluding North America and Europe. These countries have a low level of readiness for the future introduction of new technologies in general and in the maritime field in particular. This is evidenced by weaker performance across indicators for the introduction of new technologies and the limited structures in place for maritime transport. Several reasons account for the low level of readiness. One key distinction can be made across these countries which relates to their current level of maritime industries and their plans related to industrialization.

3.3 MANY COUNTRIES HAVE NOT DEVELOPED LONG-TERM PLANS FOR AUTOMATION IN THE MARITIME SECTOR

The research reveals that although several ongoing discussions about automation and autonomous ships are taking place among different actors in the maritime industry, the maritime sector is still at the beginning of its transformation compared to other transport sectors. Many countries from the selected list have adopted a strategic vision for the introduction of new and emerging technologies in the maritime sector.

In this regard, the international maritime community recently began discussions within the framework of the IMO relating Maritime Autonomous Surface Ships (MASS)[39], beginning with a regulatory scoping exercise . Many countries examined in this study are active in this sphere, including Australia, China, Denmark, France, Japan, Norway, Republic of Korea, Sweden and the United States. However, no country has to date unveiled a comprehensive strategy for maritime transport in 2040, one that combines regulations with innovation, competences and skills, infrastructure and future business models.

FINAL REMARKS

The country profiles are a snapshot of the current situation in a number of countries regarding their readiness to introduce new and emerging technologies in the maritime field. The results of this research show that there is a gap between developed and developing countries relating to different aspects of new technologies, namely, investment in new technologies and innovation, regulations, infrastructure and investment in people.

It is clear that while some countries are leading the transformation, no country to date has a global strategy that encompasses business plans, innovation, competences, skills and an adequate infrastructure.

This shows that the absence of a correlation among these factors underscores the difficulty in adopting such technologies in the maritime sector. For example, sectors like infrastructure and education require considerable levels of investments, while weak governance requires addressing corruption and absence of rule of law. The most prepared nations for the coming wave of automation and artificial intelligence are in East Asia, Europe, in particular Germany, the United States and Australia.

Chapter 4 shows that the maritime sector is still at the beginning of a technological transformation compared to other sectors. Although in chapter 5 on the four case studies the profiles show that in some areas of the maritime sector, automation is moving ahead rapidly, as in port automation. In this case study we see that some automation processes still need to overcome technical constraints. Port automation involves key technologies in many tasks which results in both higher productivity and lower costs. The case study on automated ships shows another trend: as automated ships become part of maritime transport system in the next five years many captains and engineers jobs will move to shore-based positions which will reduce the need for workers.

Truck platooning shows the uses of smart technology for convoys of trucks and serves as an example of increasing automation and connectivity in driving. Platooning leads to a reduction in fuel consumption and gas emissions, but it requires a special road infrastructure, among other challenges

The case study on automation of baggage handling at airports found that this is most likely to be found in new state of the art terminals because the various technologies are very expensive to upgrade in regular terminals. As to its impact of labour found that while baggage automation would eliminate manual jobs, skilled jobs needed to maintain the technology would create a demand for high skilled labour.

[39] See, Maritime Safety Committee (MSC) 100th Session, December 2018, MSC 100/5, Report of the Correspondence Group on MASS and MSC 100/INF.3 containing a consolidated report relating to comments on maritime safety and security instruments based on documents submitted to MSC 99 relating to the regulatory scoping exercise for the use of MASS.

CHAPTER 5

CASE STUDIES

5

1 INTRODUCTION

This chapter aims to demonstrate how specific technologies touching four different modes of transport could affect transport workers by providing four case studies. The main objective is to show how the macro trends analysed previously in this report can be manifested in specific technology applications that emerge at specific places and affect specific labour groups.

The case studies emphasize the crucial analytical topics developed in the previous chapters of this report. They also describe the complexities, challenges and opportunities of the specific cases.

While the previous chapters portray and forecast the global effects of technology and automation in the transport sector, the case studies are illustrative of a particular situation. Thus, it is not the objective of the case studies to arrive at generalised conclusions.

Four case studies are developed in this chapter: 1) Truck platooning, 2) Automatic baggage handling systems, 3) Autonomous ships, and 4) Port automation. These cases were carefully selected to show how existing technological applications can affect labour groups that are usually numerous in their respective industries. Some of the cases are already in place in commercial applications (automatic baggage handling systems and port automation), while others are in development and testing stages (truck platooning and autonomous ships).

In the case of truck platooning, trials have been conducted in a number of countries and regions around the world. Several technological challenges still exist, but the industry is attracted by the potential reductions in fuel and gas emissions. Because of the infrastructure required, truck platooning is mostly pursued by players in developed economies. In those, truck platooning has a limited potential effect on the labour force as, in some countries, truck drivers are in short supply. However, truck platooning is also a stepping stone toward totally driverless trucks - a technological application that significantly affects the labour market.

In aviation, one of the most labour intensive activities is ground handling in airports. The introduction of further automation for baggage handling is expected, especially in apron operations, to impact the manpower required to conduct the activities. The second case study provides an overview of how automatic baggage handling systems are currently implemented, highlighting the challenges and implications of such systems in regard to automation of work processes. The investigation undertaken identifies the major challenges that need to be addressed by the industry as a whole.

The third case study focuses on the case of autonomous ships. It reflects the trend of increasing digitalisation and automation in the shipping industry. The case of the Yara Birkeland ship (Norway) is taken as an example. This novel type of ship is intended to work totally unmanned (after a period of manned operations) and is attracting much attention from the industry. Naturally, the operations of ships such as Yara Birkeland are foreseen to have major impacts on the labour force because they can operate with a minimal crew or even with no crew onboard, but also because personnel controlling and operating these types of ships require a different set of skills to those required on conventional ships. The case study also highlights the challenges that the shipping industry will face regarding the introduction of autonomous ships and provides some guidelines regarding the new set of skills required for the seafarers of the future.

The case study on port automation highlights the rapid trend of terminal automation that is taking place in numerous ports in the world. The case study provides an overview of the location of automated terminals, the technological applications involved, and the factors that affect the choice of location of to-be-developed ports with automated terminals. Based on these, some implications for port workers are provided.

By undertaking the above mentioned four case studies, this chapter investigates concerns and deepens understandings of the four transport modes, which facilitates associated practitioners to have a more tangible idea of the global trends described in the other chapters. These examples aim to show how automation and technology can affect and are already systemically affecting the labour force all over the world.

2 CASE STUDY: TRUCK PLATOONING

WHAT IS TRUCK PLATOONING?

Truck platooning is the linking of several trucks in a convoy, or platoon - using state-of-the-art automated driving support systems - with one truck closely following the other. Only the lead truck has a driver, the trucks following are driverless as they are operated by smart technology. Such state-of-the-art technological advancements show that truck platooning is innovative and full of promise and potential for the transport sector.

Due to the short distances between the trucks, manual operation would lead to the high risk of a crash occurring and would compromise safety. Instead, the trucks in the platoon will automatically follow the lead truck. The lead truck is currently conceptualized as being manually driven but, as technology develops, this may change.

Technological solutions, such as sensors, vehicle communications and vehicle control, make this operation possible, as the trucks following need to autonomously brake, steer and accelerate based on the actions of the lead truck. The reaction times required to conduct these operations safely are much shorter than what a human driver is capable of.

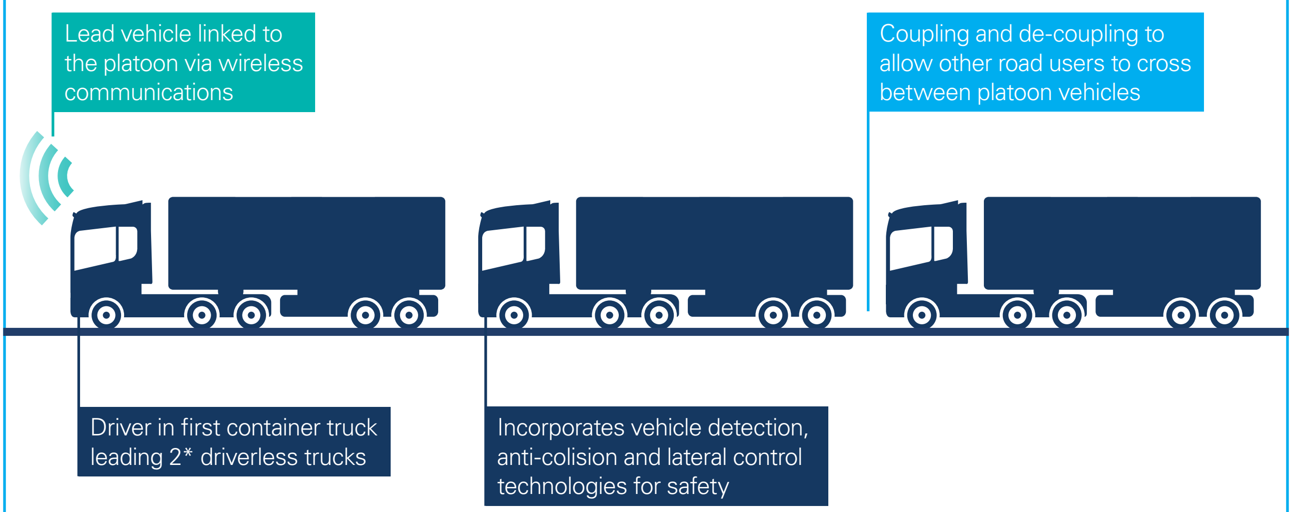
The notion of platooning is not synonymous with autonomous trucks, but is an example of increasing automation, autonomy and connectivity in driving. Trucks are seen as being able to platoon in specific situations and locations. Once the platoon is disengaged, manual operations are resumed. However, truck platooning is also a step closer to autonomy, as the technical system will perform more and more aspects of dynamic driving.

WHAT ARE THE INCENTIVES?

The main benefit of truck platooning is the reduction in fuel consumption, which also means a decrease in emissions of pollutants and greenhouse gases. Studies and trials report savings in fuel consumption from 5 to 12 per cent. Other studies report savings of up to 20 per cent.

In addition to reduced fuel consumption and gas emissions, platooning is said to improve safety. For example, some equipment necessary for platooning, such as the Advanced Emergency Braking System (AEBS), can reduce rear-end crashes by about 80 per cent, even for trucks that are not platooning. And as platoons need to be planned and coordinated, less traffic congestion can be expected as less road space will be necessary given the short spaces between the vehicles. Also, drivers of the following trucks will have a lighter workload while platooning, which may be a positive factor for the industry, particularly in developed countries that face labour shortages.

ONE DRIVER, MULTIPLE TRUCKS



*Number of trucks in each platoon may vary according to trial results.
Source: PSA and Ministry of Transport

WHAT ARE THE CHALLENGES?

Truck platooning faces several challenges. They include the creation of a special road infrastructure, reliable vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, informative driver-vehicle interfaces and the development of a regulatory framework at the national and international levels.

For some smaller players, the cost of retrofitting the equipment of current fleets, or buying new trucks able to platoon, can be a challenge. Apart from the cost, the percentage of journeys that can potentially be done by a platoon is currently limited. Traffic, road conditions and the digital infrastructure required (e.g., V2I communication) are examples of limiting factors. In addition, platooning opportunities may vary depending on the operators. Small fleet operators might have fewer chances to platoon if cooperation and coordination between different fleets and operations is not achieved.

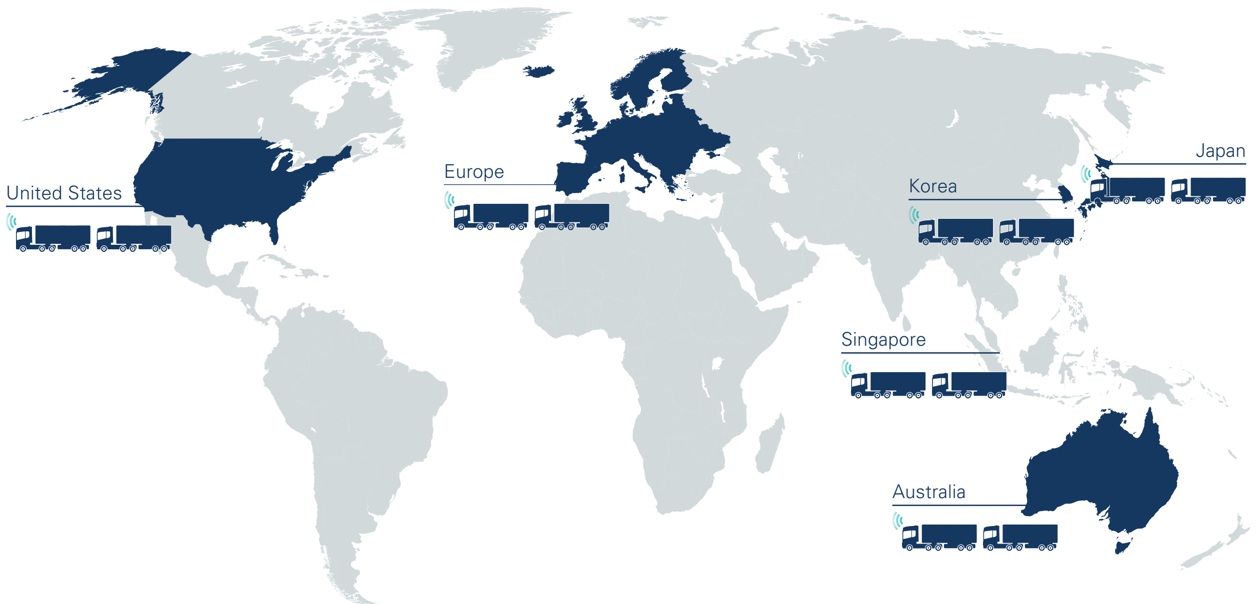
Truck platooning is likely to affect labour markets. At first workload of the following trucks is reduced, reducing the pressure on the demand for truck drivers. With the emergence of driverless vehicles, some players have advocated for a driverless operation of the following truck, further reducing the demand for truck drivers. Depending on the country, challenges may arise as labour markets are disrupted by technology.

In the case of truck platooning, research is also considering whether the load on road pavement and structures, such as bridges, could be a concern. To date, no consensus has been reached. The industry and research institutions have highlighted other problems relating to the transition between automatic driving mode to manual mode, to inattentive drivers (those following the lead truck) or to interaction with other road vehicles.

INITIATIVES AROUND THE WORLD

Platooning trials have been conducted or are underway in Australia, Europe, Japan, Korea, Singapore and the United States (Figure 5.1). Several countries have put forward road maps aimed at multi-brand platooning (with sustained lateral and longitudinal vehicle motion control performed by the system - up to the Society of Automotive Engineers (SAE) level 2 of road vehicle automation). Such road maps predict that truck platooning at that level of automation can be attained between 2025 and 2035.

FIGURE 5.1 Truck platooning initiatives around the world



Source: WMU composition

Further readings:

Slowik, P. and Sharpe, B., "Automation in the long haul: Challenges and opportunities of autonomous heavy-duty trucking in the United States," International Council on Clean Transportation Working Papers 2018-06.

Bhoopalam, A. K., Agatz, N. and Zuidwijk, R., "Planning of truck platoons: A literature review and directions for future research," Transportation Research Part B: Methodological. Vol. 107(C) 2018, pp. 212–228.

Austroads, "Operation of Automated Heavy Vehicles in Remote and Regional Areas." The report was prepared by Anthony Germanchev, Ronny Kutadinata and Steve Shladover (Sydney, Australia: Austroads Ltd., 2018 . Retrieved from https://cdn2.hubspot.net/hubfs/3003125/Heavy%20Vehicles%20remote%20areas.pdf?t=1542339427742

3 CASE STUDY: AUTOMATIC BAGGAGE HANDLING SYSTEMS

WHAT IS BAGGAGE HANDLING?

The baggage handling system installed in airports transports checked luggage from ticket counters to areas where the bags can be loaded onto airplanes. The process of baggage handling starts when a passenger checks in baggage at the airport. This is usually at the same time as the check-in for a flight.

With the increasing use of online check-in, more bags are being dropped off separately or through self-service check-in kiosks or bag drop counters. Baggage labels, or tags, are attached during check-in, which contains information such as airline, flight number and destination airport code. A bar code or RFID tag can be scanned/read, which allows the tracking of the bag and its linkage to other information such as the weight, or travel class category (e.g. priority, business or first class). Bags will then need to go through security checks, after which they are delivered to the sorting and loading areas to be loaded into containers (unit loading device, or ULD).

In airports with automatic cargo/baggage handling systems or early baggage storage areas, bags can be temporarily stored until shortly before flight departure.

Up to this point, most operations are performed inside airport terminals, although in many cases facilities - e.g. check-in counters/kiosks, baggage conveyor and storage, screening systems - may be owned by or leased to airlines. After being sorted and loaded into ULDs, bags are then delivered and loaded into the aircraft prior to flight departure. These operations are usually performed by ground handling service providers, which may be owned by the airport, the airline, or independent third-party companies.

This process is reversed for arrival flights: baggage ULDs are off-loaded from aircraft and delivered to airport terminals. Bags are then loaded and transported by conveyors to the carousels for baggage claim. In the case of connecting/transfer flights, bags may be temporarily stored until they are re-sorted and loaded onto the next flights.

AUTOMATION OF BAGGAGE HANDLING

The aviation industry has been investing heavily in baggage handling systems to improve efficiency, reduce costs, increase reliability and control mishandled baggage. Automation is one major medium to achieve these objectives. For example, whereas the screening of carry-on bags is still performed manually, in most airports the screening of check-in baggage has been automated. Only a very small percentage of bags that failed automatic check will be manually inspected. Bag transport, storage, retrieval and loading can all be fully automated (Figure 5.2).

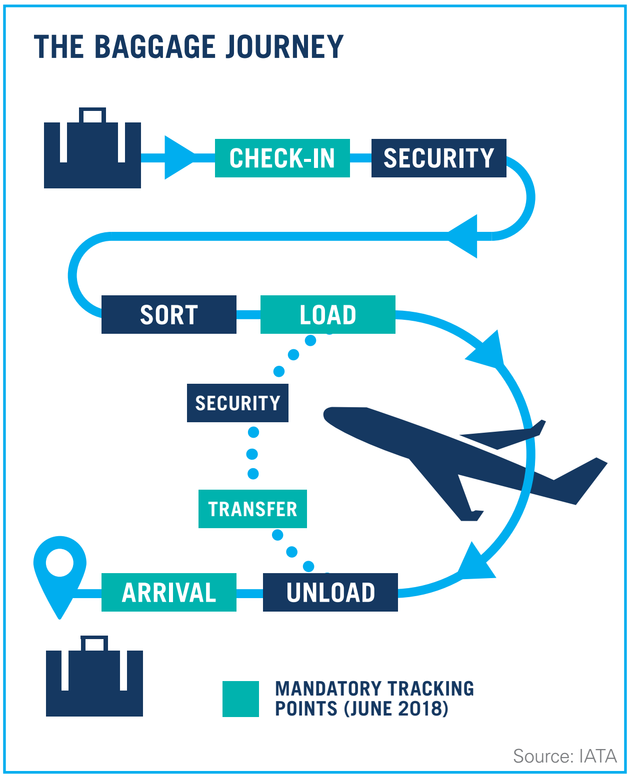
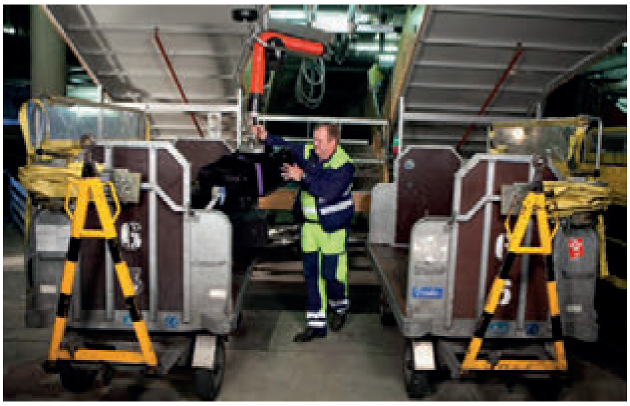


FIGURE 5.2 Manual baggage loading with lift solutions vs. automated baggage loading



Source: http://www.vaculex.com/solutions/airports/ [Accessed 3 Jan 2019].

Source: https://www.airport-technology.com/contractors/baggage/grenzebach1/ [Accessed 3 Jan 2019].

FIGURE 5.3 Automated baggage sorting and screening systems

Source: https://www.airport-suppliers.com/supplier/beumer-group/ [Accessed 3 Jan 2019].

Source: https://airportimprovement.com/article/upgraded-baggage-system-takes-over-commuter-apron-pittsburgh [Accessed 3 Jan 2019].

Figures 5.3 illustrates the automated transport and sorting systems and facilities for automated baggage screening. In the aviation industry, proposals also exist to use autonomous vehicles (AVs) to navigate baggage carts between airport terminals and aircraft. However, few systems have been actually implemented to date. A few companies are also designing AV-based baggage distribution systems within airport terminals.

However, even with the fully automated systems installed, human/manual interventions are frequently needed. For example, the delivery, storage, screening of oversized baggage items are usually handled manually. The processing of specialized items, such as certain medicines, blood samples or even service dogs, also requires manual intervention. Although artificial intelligence applications are being developed, human surveillance and security controllers are often needed during operation. Automated systems also involve a lot of maintenance and upgrading activities. Whereas demand for low-skilled labour may be reduced through automation, there may be an increase in high-skilled jobs.

WHAT ARE THE CHALLENGES?

The research undertaken for this study found the following challenges:

- Information-sharing is one important requirement for baggage automation and tracking. However, the operation of and investments in baggage systems involve many stakeholders such as airports, airlines, ground service providers and Government regulators, sometimes in different countries. It is not always easy to fairly allocate the benefits, costs and responsibilities. In addition, many globally accepted standards and protocols, which would serve as a guide for the aviation industry, are yet to be agreed to.

- Baggage handling systems are sophisticated and expensive. Maintenance costs also tend to be high. Airports prefer to adopt automation systems with proven reliability at reasonable costs. Whereas airports may choose advanced technology for newly built terminals, they may be conservative in upgrading existing infrastructures.

- Institutional factors play important roles in airports' and airlines' automation decisions. If airlines and airports cannot fully benefit from automation, they will be reluctant to make the needed investments. Therefore, Government policy and regulation will play important roles in such decision-making.

KEY FINDINGS

Baggage automation will be progressively introduced in the aviation industry, especially in newly built terminals, large airports, and markets where stakeholders can work jointly. International organizations and government agencies have important roles to play in such a process. The aviation industry is quite competitive and dynamic. Airlines and airports need to constantly improve their service quality and standards. At the same time, major aviation markets are often located in high-growth developing countries or high-income developed countries with a shortage in the supply of specialized labour. In the short to medium term, baggage automation is unlikely to bring major destructive shocks to the labour market.

4 CASE STUDY: AUTONOMOUS SHIPS

The introduction of novel technologies is a continuous process that has been taking place in different phases and in varying degrees. At first, individual electronic components were connected (e.g. steer by wire control). When computers first came on the scene, analogue components were replaced by digital components that provided a wider range of operations (e.g. decision support, using data provided ashore). The arrival of *autonomous* systems, that can take decisions on their own but are supervised by human operators, introduced more support in decision-making. Today, the shipping industry is making progress on two fronts: it is moving towards greater digitalization and the development of autonomous ships for specialized operations in national waters.

Autonomous ships are not conventional vessels without a crew; rather they are a novel type of ship with fewer but highly skilled crew members who control an increasing number of autonomous functions and operations on board, possibly from remote control stations.

However, several challenges need to be addressed: user interfaces must make it possible for a remote operator to maintain situational awareness; a review of a number of IMO instruments, including the Convention on the International Regulations for Preventing Collisions at Sea, 1972 (ColRegs), must be undertaken to address and resolve issues that need to be addressed before digitalization can occur; there must be procedures put in place that address a mixed traffic of manually operated and autonomous ships; a reliable data connection must exist between ship and operating centre(s); and deep learning functions for processing the amount of data that is collected aboard must be implemented. Account must also be taken of the fact that the safety assurance of autonomous systems is not to date a mature discipline.

Given the agenda of Maritime Autonomous Surface Ships (MASS) Working and Correspondence groups at IMO, international regulations for autonomous ships are expected to be in place before 2035 (DNV GL "Energy Transition Outlook 2018"). But for specific operations in national waters, inland or near-coastal waters, it is anticipated that autonomous ships may be navigating the waters by 2028.

For example, in Norway, YARA Birkeland is under development: it is a fully electric autonomous container ship, carrying fertilizer products from YARA's production site in Herøya to the nearby ports in Brevik and Larvik in Norway's southern Telemark region. This vessel is revolutionizing ways in which supply chain transport is practiced in Norway. It is a specific business model that is operating in a very specific setting in that country. If successful, this model may be successfully replicated in similar cases around the world.

Phase 1 of the building of the YARA Birkeland will begin as a remotely controlled and manned vessel within three to five years. In the following years one will see a shift to remote control-unmanned and finally to autonomous-unmanned. The last two phases point to a shift from decision-support to decision taking, although shore-based supervision is expected to remain a central activity.

As to the effects of such cutting-edge technologies on seafarers, a number of lessons learned have been noted:

- Autonomous ships will not replace conventional cargo ships which could result in the lose of jobs for seafarers. It is expected that autonomous ships will be developed as part of a local transport system, which means they will, create new nautical routes as an alternative to other transport modes.
- As the current "digitalization" of the conventional fleet proceeds apace, the tasks of seafarers will change to more digital ones, especially in operations monitoring and system management, and in less operational work. Education and training will need to be adapted to equip seafarers with the new skills required.
- More plans for autonomous ships can be expected as part of total transport systems that will emerge in the next five years.
- In Norway, seafarers working on inland ferries navigating short distances are at risk of losing their jobs as autonomous operations come of age. Captains and engineers are at special risk of being moved to shore-based positions, which will limit the need for personnel on board. Changes to technology that allow autonomous operation are already taking place in inland ferries.
- The seafarer of the future will benefit by combining maritime skills with digital skills in three general domains:
  - data fluency and ability to interpret and analyse large amounts of data
  - digital operation of equipment such as ships, cranes and winches.
  - software engineering of fundamental programmes and systems.

FIGURE 5.4 Applications of digitalization and automation in maritime fleet support and road passenger transport

▲ YARA BIRKELAND – FULLY ELECTRIC AUTONOMOUS CONTAINER SHIP

(Launch: 2020 expected) (© Kongsberg Maritime)

Voyages: Herøya – Brevik (7 nm), Herøya – Larvik (30 nm)
Length: 80 meters; Width: 15 meters
Service speed: 6 knots; Deadweight: 3 200 mt; Load capacity: 120 TEU

5 CASE STUDY: PORT AUTOMATION

WHERE ARE THE AUTOMATED PORTS?

Port operators are generally more proactive in carrying out automation in comparison to shipping carriers in regard to their deployment of autonomous ships. Nevertheless, both shipping carriers and port operators believe that an automated terminal can be built in a restricted area in one country, where it would come under the national jurisdiction of the country concerned. However, as regards autonomous vessels that navigate the waterways of many countries, or undertake voyages at sea, both national laws and international conventions have to be complied with.

Therefore, decades ago, when making a decision on building automated terminals, concerns on potential operational or environmental accidents focused mainly on complying with relevant national laws, without spending undue time on negotiating and complying with international conventions. At that point in time, automated terminals in restricted areas were less likely to be subject to the legal constraints of international regulations, which led to the rapid development of port automation compared to the launch of autonomous ships on a commercial basis.

In 1993, the East Container Delta Terminal in Maasvlakte Rotterdam was the first fully automated container terminal in the world. Later, the Port of Rotterdam, as a port authority, also organized more terminal operators and expanded the scale of automation - the Delta Dedicated East and West Terminals, Euromax, Rotterdam World Gateway and APM Terminals, who are now operating in Maasvlakte Rotterdam as well.

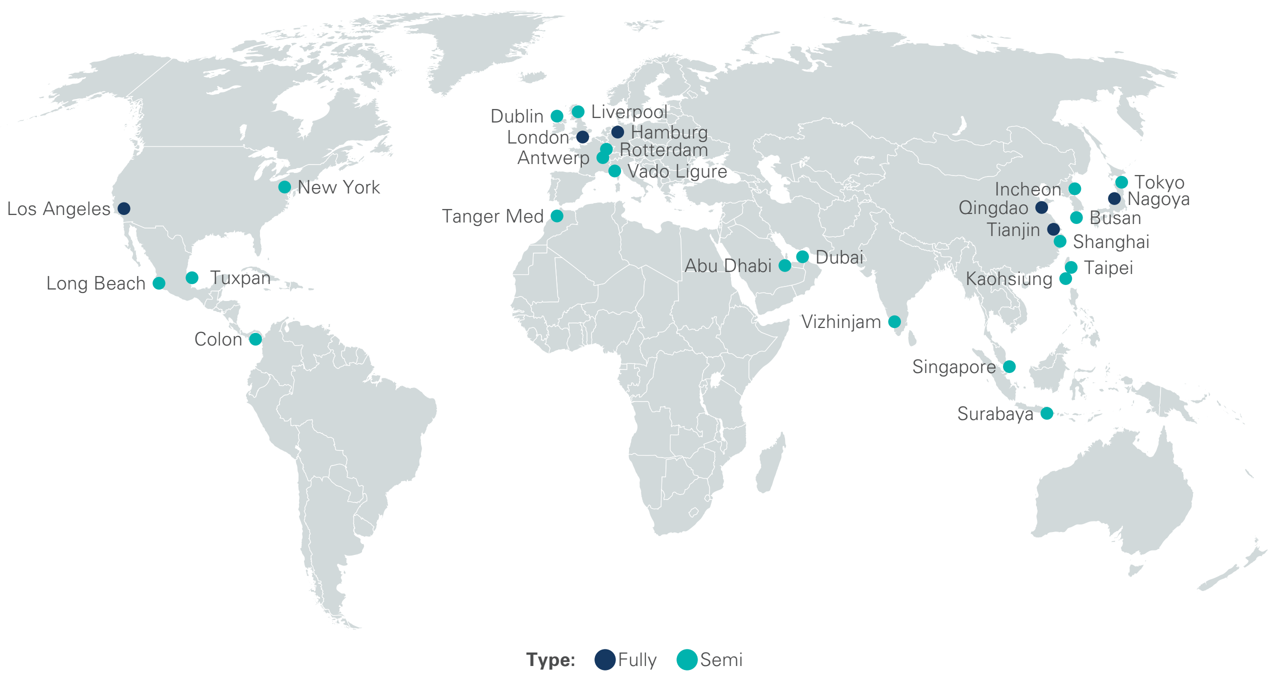
In 2002, the Container Terminal Altenwerder in the Port of Hamburg implemented the second fully automated container terminal in the world. Hamburg also has another semi-automated terminal, namely, the Container Terminal Burchardkai.

In December 2017, Yangshan Phase 4 Container Terminal in China became the largest fully automated container terminal in the world. In total, 60 container terminals are either fully automated or semi-automated today, according to the Review on Maritime Transport (UNCTAD, 2018). By end of 2017, 38 ports are reported to be operating 60 automated terminals, which include 14 fully automated terminals. The geographical areas of the automated container terminals is shown below.

In addition to the above-mentioned 60 terminals, the Tuas Terminal in Singapore announced its interest in May 2018 to develop a new automated terminal. Presently, Singapore has semi-automated container terminals in operation, the Pasir Panjang Terminals 1, 2, 3 and 4.

Ports that are taking the lead in automation include: Brisbane, Melbourne and Sydney (Australia); Antwerp (Belgium); Qingdao, Shanghai and Tianjin (China); Hamburg (Germany); Vizhinjam (India); Surabaya (Indonesia); Dublin (Ireland); Vado Ligure (Italy); Nagoya and Tokyo (Japan); Lazaro Cardenas and Tuxpan (Mexico); Tanger Med (Morocco); Rotterdam (the Netherlands); Auckland (New Zealand); Colon (Panama); Singapore; Busan and Incheon (Republic of Korea); Algeciras and Barcelona (Spain); Dubai and Abu Dhabi (United Arab

FIGURE 5.5 Selected geographical locations of automated container terminals



Source: UNCTAD (2018), WMU composition

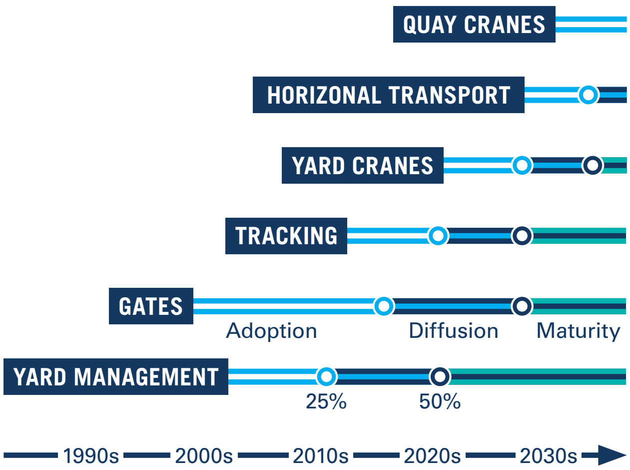
Emirates); Liverpool and London (United Kingdom); Long Beach, Los Angeles, New York and Norfolk (United States); Kaohsiung and Taipei (Taiwan Province of China) - Figure 5.5.

WHAT TECHNOLOGIES ARE READY?

The concept of technology readiness level (TRL) is introduced as an indicator of technological maturity. It has been investigated by many market reports and academic literature (van Cappelle, Chen and Negenborn, 2018). In general, existing and near future technologies of automation in ports can be presented (see Figure 5.6), including levels of adoption, diffusion and maturity.

Future technologies related to automation in ports together with the future introduction of autonomous ships appear in Table 5.1.

FIGURE 5.6 Key Terminal Automation Technologies



Source: https://transportgeography.org/

TABLE 5.1 List of contemporary and future technologies to advance automation in ports

KEY TECHNOLOGIES	SAMPLE APPLICATIONS IN AUTOMATION IN PORT
Advancements in robotics	AGV
Common data repositories	Port community
Advances in autonomous modeling and simulation	AGV, TOS, truck routing and appointment APP, port community
Advances in machine learning	AGV, TOS, truck routing and appointment APP
Advances in artificial Intelligence	Yard management
Advances in SWaP/miniaturization	Sensors, AGV, gate entrance control, cargo tracking
Swarming capabilities	Waterway ship scheduling, ship platooning
Augmented reality	Gate entrance control
Virtual reality	Waterway ship scheduling
Sensor advancements	Gate entrance control
Collision avoidance	Waterway ship scheduling
Leader-follower mechanism	Ship platooning, autonomous ship berthing
GPS-denied solutions	AIS, truck routing and appointment APP
Cyber resilience and robustness	Waterway ship scheduling
Information assurance solutions	Inhouse management information systems
Increased network and spectrum capacity	Cloud computing for task pooling, and on-line traffic control
Human-machine interface advancements	Remote control of quay cranes, gate entrance control
Autonomous data strategy adaptation	Port community

Source: U.S. Department of Defense, Unmanned Systems Integrated Roadmap 2017-2042 (2018), WMU composition.

WHAT FACTORS DETERMINE THE LOCATION OF A NEW PORT?

One of vital factors of influencing automation in ports is technological readiness. Other factors are listed as follows.

ECONOMICS BENEFITS

The economic benefits of automation are twofold: 1. From the perspective of a technology supplier, in the long-run, the benefits of Research and Development investment,[40] if successfully implemented, would result in higher productivity and lower cost borne by the technology users, i.e., automated container terminals operator; 2. From the perspective of technology users, in the short-term after deploying automation, the unit operational cost is expected to decrease and profitability is expected to increase.

For example, automated multimodal interchange of containers between yard and train is being tested in the container terminal in Rotterdam. In the hope that pilot tests will be successful and implementation will be more extensive in scope, more rail mounted gantry cranes can be installed along train gauges within the boundary of the automated container terminal in Rotterdam. As a consequence, the multimodal interchange cost per container is expected to be more reasonable.

REGULATION AND GOVERNANCE

A significant difference exists between policy and regulation. Policy allows choices, but a regulation is made and maintained by an authority. This differentiation helps to better understand the concepts of regulation, governance and policy instruments. One of the merits of the Port of Rotterdam is that it proactively established policy and port governance rules on using clean energy. For example, while designing the layout of the automated terminal, a battery station was included that support battery exchange services for AGVs by using wind energy via adjacent on-shore and off-shore wind turbines. In this case, the application of automation technology, i.e. that of AGVs, was influenced by relevant regulations and rules that have been adopted.

In addition to environmentally friendly terminal facilities, a range of policy instruments can be applied to support a port's strategic orientation. They include incentive schemes, training and education, platform organizations and knowledge transfer schemes to attract high value-added port-related companies that could make the port a benchmark for implementing technologies. For example, the Port of Rotterdam provides a comprehensive package and toolkits for the purpose of training so as to leverage the knowledge and capacities of its labour force.

SOCIAL ACCEPTANCE

In terms of social acceptance in regard to implementing automation in ports, in the case of dry bulk terminals automation has existed for long time which means that social acceptance has not been an issue. In container terminals of the Port of Rotterdam, when reskilling quay crane drivers into remote-controlled quay crane drivers took place, the associated learning curves were not as promising as expected. This was partly due to a variety of requirements in 3D and 2D handling and to a lack of social acceptance of technological change and its impact on jobs.

Currently, remote-controlled quay crane handling is being tested, but it is not yet operational. In addition, in the Port of Hamburg, where inland waterway ships are berthing and handled, on-shore dockers have insisted on keeping lashing as their task and have not agreed to seafarers undertaking this work. This demonstrates the low social acceptance of giving up manual tasks, even if lashing tasks for inland waterway ships requires a very limited number of workers. Currently, some institutes are interested in researching automated lashing and twistlocking systems, although, they are a long way from becoming operational.

WHAT ARE THE DIFFERENT JOB SKILLS NEEDED AND WHAT IS THE IMPACT ON EXISTING JOBS IN THE PORT INDUSTRY?

Current positions in ports and port-related services include first line supervisors, industrial truck operators, crane operators, construction workers at operational level, construction specialists, maintenance workers, equipment dispatchers and shift managers.

Future job profiles and the knowledge and skills needed are very much associated with the trend of automation. For example, the overall high-risk of automation faced by dockers depends on the actual job content. Dock workers are mostly low and medium-skilled according to the ILO classification of occupations. Even for geographically adjacent countries or countries with a similar stage of economic development, the risk of automation varies substantially.

The differences are due to the variation in the content of their jobs' tasks from country to country. A stevedore in Korea can do a very different set of tasks than one in Japan, a fact that is reflected in the automation statistics in Chapter 3. One concern which our research points to is that for most countries further automation is expected and will in many cases lead to job elimination or to redundancy.

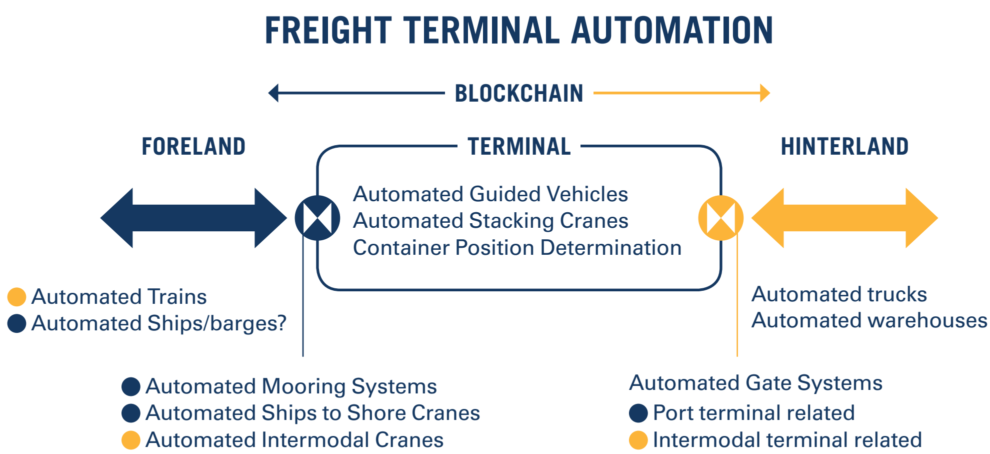
Contrary to their seafaring counterparts, dockers presently face and in the future will continue face a much higher degree of automation. Most dockers' jobs will have a high potential for task automation by 2040, and most are already experiencing this trend as part of the transformation taking place today. For example, for lift truck operators the current automation level is currently less than 40 per cent on average but it could reach 90 per cent. By 2040, a rate of 90 per cent task automation is projected for crane operators and dockers in general.

In order to understand the skills required in major areas of port operations in the context of automation, these can be categorized as follows: terminal operation, including waterway ship scheduling service; foreland transport service, including railway and road transport service connected to the port; hinterland transport service, including railway and road transport service connected to the port; and warehouses related to the port (see Figure 5.6).

In regard to the section of terminal operation shown in the centre of Figure 5.6, for example, the requirements of being a remote-control driver of the automated quay cranes actually become amplified and more complex than those of traditional quay crane operators. This is quite different from the assumption made at the outset, i.e., that automation would

[40] See, for example, Cargotec (2017).

FIGURE 5.6 Process and Perspectives of Automated Terminals in the Future



Source: https://transportgeography.org/?page_id=3088

make the working life of workers directly involved much easier. It is compulsory for the "new" quay crane drivers to obtain general prior knowledge on mechanics and electronics, in addition to state-of-the-art handling skills on control panels. This is because they have to preliminarily ascertain what bug occurs in the information system, for example, before IT specialists come on-site. For the "older/experienced" quay crane drivers, general knowledge is actually not required, and only specialized handling skills on operating the cranes are compulsory.

IMPLICATIONS FOR PORT RELATED WORKERS

CHALLENGES

Performance, or the numbers of 'moves' per hour, comparing before and after automation, might not dramatically increase the given level of technological readiness and the current level of human-machine interaction. In other words, the advantages of automation in ports should be considered within the context of human-machine interaction. In some cases, a delay in reaching expected productivity levels can occur due to many different innovations being introduced simutaneously without sufficient integration, and an attendant lack of overall control.

While technolgoy is a key enabler, it is not the only factor influencing terminal productivity. The human factor is important in this context. Reported challenges to the wider implementation of port automation solutions include costs, a shortage of skills or resources to implement and manage automation, the concerns of labour unions and the time required for implementation.

With respect to labour, Vonck (2017) focusing on the maritime cluster in the Netherlands finds that the number of jobs in the maritime cluster will decrease by at least 25 per cent with the advent of automation. Jobs in the port sector are projected to drop by 8.2 per cent (Vonck, 2017; UNCTAD, 2018).

OPPORTUNITIES

Many practitioners in the transport industry regard the rise of automation as a phenomenon that will displace or eliminate jobs. However, automation may improve safety, security and welfare for port workers. In this respect, retraining and reskilling is needed to take advantage of the potenal increment in welfare.

Retraining is needed, especially with regard to semi-automated terminals where dockers are still needed. The terminal operation system is normally developed by the associated terminal operator or the port group it belongs to. Therefore, different terminals in one port might have different standard operational procedures, with which a non-permanent-contracted docker has to comply.

This docker might work for two different terminals, each one with its own schedule. Retraining will be needed, especially when fully automated terminals are concerned and dockers have opportunites to switch duty stations. Highly efficient planning, scheduling and equipment dispatching, realizing remote control of ship handling, inspection on unmanned yard handling, and inspection on horizontal transport will be required. These are all procedures in fully automated terminals where "new dockers" will be needed and who will be relocated hopefully to an improved working environment involving less labour intensive work.

In summary, a broad range of technologies with applications in ports and terminals offers an opportunity for port stakeholders to innovate and generate additional value in the form of greater efficiency, productivity enhancement, as well as greater safety and heightened environmental protection that have a positive impact on the health of dockers. Education and training will be sine qua non requirements for port workers.

KEY FINDINGS:

- Port automation is developing rapidly.
- Some automation processes in ports, such as lashing and twistlocking, still face considerable technical impediments.
- The workforce in ports needs training and reskilling.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Automation and technology will continue to have significant implications on the Future of Work as history has demonstrated. The difference today is the speed and pace of these technological developments and the transformation they are or might have, including on the workforce and on work processes. This report discusses the evolution of jobs and employment in the transport sector and the prospect that new technologies might transform jobs and the labour force on a systemic scale by 2040.

While automation and technology have the potential to transform future jobs and the structure of the labour force, this study has found that the introduction of automation would be evolutionary rather than revolutionary on the macro level. The global demand for transport workers will change due to the advances in automation and technology. Technology has the potential for reducing manpower requirements, but the trend in the expansion of international trade can counterbalance such reduction. Overall, the forecast projects a need for more transport workers in the future.

There is a correlation between trade and transport. As higher levels of automation and technology are introduced in transport, this sector will become more efficient leading to greater productivity. This, in turn, will lead to a new pattern of transportation routes which is forecasted to bring modal shifts at the regional level. At the same time, the global demand for transport workers will change due to the advances in automation technology. Overall the transport volume is expected to increase by 2040, but at a decreasing rate. The trends towards increased levels of interconnectivity in production processes and advanced levels of automation will continue to have effects on all transport modes in the future.

However, the impact of automation and technology on the transport labour force from now until 2040 would vary across skills and tasks. While there is a similar potential for automation in transport as in other industries, the report suggests that there would be a slower adoption rate in transport and particularly more so for developing countries. The introduction of automation technologies that is expected to make some low- and middle-skilled jobs redundant will vary from country to country as factors other than technical feasibility come into play. Tasks performed by high-skilled groups are least prone to automation since automation and technology are often introduced to assist high-skilled workers so they can focus more on their core tasks. The objective is to complement their work rather than replace them, whereas a large proportion of core tasks for low- and medium-skilled groups have a greater potential to be automated.

A complex number of factors, such as skills, tasks, labour costs, demography or transport modes, determines the level of impact created by technology and automation on the labour force. For example, ageing and/or a comparatively high-wage workforce face a greater risk of being impacted by a higher degree of automation, while the economic incentives for automation are less advantageous for a younger and/or lower-wage workforce. Besides the demographic and long-term economic benefits, factors such as safety and efficiency can trigger further automation.

This report also shows differences in risk of automation of jobs across countries with similar economic and technological development. The risk varies substantially across the more industrialized countries: between 5.7 and 50 per cent of low-skilled workers (e.g. dockers, baggage handlers) are exposed to a high risk of automation as more than 70 per cent of the tasks are automatable. It is anticipated that by 2040 their jobs will not exist in their current form. The same applies to the middle-skilled group (e.g. able seafarers and heavy truck drivers), where the share of employment at high risk of automation is as low as 7 per cent or as high as 23 per cent, depending on the responsibilities relating to the job. Yet, for high-skilled workers, the report found a constant across countries, namely, that only up to 2 per cent of high-skilled workers are at high risk of automation. The high-skilled group (e.g. ship officers, aircraft pilots and professionals) has the least estimated potential for job loss resulting from the introduction of automation technologies. The estimated numbers refer only to their technical feasibility. The magnitude of the estimates could be reduced when considering all the others factors that determine technology adoption: economic benefits, regulation and governance, social acceptance, knowledge and skills, and labour market dynamics.

Given these projections, the importance of requalification and retraining of workers will be key in the successful transition of workers to this age of automation and technology. In line with other studies such as World Economic Forum (2018), the research undertaken forecasts that the advancements in automation and technology will lead to a reduction of workers for certain tasks, which would be offset by a growing demand for new roles. For example, in the maritime sector, remotely controlled automated ships could result in elimination of certain jobs on ships, although this is not likely to happen before 2040. At the same time, jobs with different skills are created ashore in monitoring or remotely controlling ships from shore based operational centres. Transport workers need to be prepared for the potentially difficult transition by adapting their skills and training to the emerging technological paradigms, despite the positive effect of growing trade. Looking ahead, most countries have not elaborated long-term plans for automation in the maritime sector.

As highlighted above, in some cases a decrease in jobs in transport is offset by an increase in other parts of the transport system. Some jobs may involve a different set of skills requiring retraining and requalification, or the acquisition of new skills. There is also the risk of a skills mismatch, and the gender dimension to be taken into account. One important question is who will bear the costs - companies or Governments? Business cannot rely on the Government alone and will need to recognize that human capital investment is an asset rather than a liability. For their part, policy-makers, regulators and educators will need to play a fundamental role in helping those who are displaced to be re-skilled or retrained. The question also arises of the new policies that will need to be adopted and implemented at the relevant levels, namely as appropriate by international organizations, national or regional bodies within a country, local companies or social partners.

The introduction of new technologies, robotics and AI has created ambiguity even among leading academics writing on the subject. Thus in terms of the theme of this report, forecasts on the impact of automation and technology on the transport sector are also not 100 per cent unerring. This is evident in the varying scenarios of the different forecasts and mathematical models used to predict the impact of innovative technology on workers and the labour market by 2040. Some authors believe that rapid technological change has been destroying jobs faster than it is creating them, while others assert that no historical pattern shows these shifts leading to a net decrease in jobs over an extended period.

Looking ahead to 2040 the principal trends are clear - the fundamental pace of change is accelerating. In general, while the range of required skills varies from sector to sector, workers in all sectors, including transport, will need to become more adaptable in the future, as automation and new technology adoption transform the workplace. In particular, low- and middle-skilled jobs in the transport sector face the greater prospects of redundancy by 2040 compared to their high-skilled peers where automation is often introduced to complement their tasks, although studies point to a shift in the labour force as new technologies create new types of jobs.

While there are indicators that companies in certain countries are willing to retrain workers, in others companies plan to hire new staff to fill high-skilled jobs. More studies would be needed to assess the impact of automation and innovative technologies for the society in general and investments needed to be made to address the different skills gap to match the new technologies. The transformations occurring will require continuous retraining and requalification to accompany this constant change. Governments will have to address the challenges of automation and new technologies through the regulatory framework or other appropriate modalities. Clearly, the retraining of workers and changing curricula in schools and universities in coming years will determine outcomes in 2040, while Government regulatory interventions will be needed to adjust the macro environment.

Upgrading of all workers' skills on a continuing basis, retraining and redeployment of some employees (for example, engineers on ships being transferred ashore) are necessary for dealing with the social ramifications of workers being displaced or having their jobs eliminated. The narrative is also about societal change because adaptability and flexibility will be the hallmarks of the new era.

In emerging economies, the impact of automation on employment is more attenuated than in more advanced economies as automation rates are projected to be lower, leading to smaller percentages of displaced workers, lower levels of capital investment and smaller productivity increases.

Looking at different geographical regions where medium-skilled labour prevails in transport, that reality signifies that all regions face a considerable risk of automation, although variables, like socioeconomic and demographic factors, will affect the introduction of automation in different geographic locations. Nevertheless, society must manage the skills gaps that have widened with the adoption of new technologies as the time to proactively act is narrowing down.

The risks of not being ready for the coming wave of technology and automation means falling behind. For instance, Republic of Korea, Germany, Japan and Singapore are some of the leading countries on emerging technologies. In terms of Research and Development expenditure as a percentage of GDP, the amount spent in 2015 by following countries is as follows: Republic of Korea spent 4.23%; Japan 3.28%; Sweden 3.26%; Finland 2.90%; Germany 2.88%; and the United States 2.79%.[41]

The gap is widest between developed and developing countries. As the report points out, the introduction of automation and new technologies requires significant investment in infrastructure, education, bridging the digital divide, training and research to create the conditions for this new technological age. The African and Latin American countries, including middle-level income countries such as Brazil and Ghana, would have the most catching up to do in terms of introducing technological innovation, investment, regulation and infrastructure, including in the maritime sector.

The 4th Industrial Revolution is creating a large divide between countries socially and economically, and the increasing inequality in advanced economies between low-skilled and high-skilled workers will cause imbalance on a number of levels. Some forecasts focus on the question whether low-skilled workers have a realistic future, a theme that has become part of the public discourse in the United States and the EU, and is causing apprehension. In that regard, a lack of skills and the need for adaptation call for improved the educational systems and the regulatory environment. The new types of jobs will require highly skilled workers and preparation for this important transition is required.

In order to deal with the challenges involved in the complex development related to automation and technology in transport, policy options are presented in the next section.

[41] World Bank. Retrieved from https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS.

RECOMMENDATIONS

The report would put forward a number of recommendations for further consideration and action. They focus on five areas: raising awareness for the implications of the developments of automation and technologies in transport, facilitating dialogue among stakeholders, establishing national policies to address the effects of automation innovation, highlighting the need to support developing countries, as well as educating the skills for the future.

1. RAISING AWARENESS FOR THE IMPLICATIONS OF FURTHER INTRODUCTION OF AUTOMATION AND TECHNOLOGY INTO TRANSPORT SYSTEMS

There is a need for raising awareness for the upcoming developments in the transport sector as a result of further technological development. The objective is to have informed discussions among all stakeholders, including the labour force potentially impacted, on the ramifications of systemic change brought by automation innovation.

To that end, roadmaps for the development and implementation of different new technologies and further levels of automation in transport could be created. There is a need for more research, including a focus on local- and industry-specific sectors, is needed as input for these roadmaps. This report can be seen as an example for such input aiming at establishing a data-based foundation that would allow for a better and objective understanding of timelines involved as well as vital parameters that amplify or attenuate the development and introduction of automation innovation.

Mapping exercises between current practices and expected future ones would be an essential pre-requisite to understand the dimensions of change and the implications resulting from technological development in transport. Important questions to be addressed in these mapping exercises would be which jobs could be created as a result of new technologies and automation and what skills would be needed in a technology driven future to effectively operate the new transport systems.

2. FACILITATION OF INTENSIVE DIALOGUES BETWEEN STAKEHOLDERS IN GLOBAL TRANSPORT FOR A BETTER UNDERSTANDING OF THE DIFFERENT POSITION OF ALL PARTIES CONCERNED

The dialogue between all stakeholders in transport from politics, industry and academia should be intensified on a global basis in order to better understand the future challenges and to discuss options to effectively address the different dimensions of complexities associated with the changes in the nature of work in transport as a result of the further introduction of technology and automation. Even though the pace of change as a result of further automation and technologies in transport is evolutionary rather than revolutionary, the time to prepare for adaptation of the labour force potentially affected is limited.

Social acceptance of more technologies and higher levels of automation will to a certain extent also depend on the effects that the introduction of automation innovation creates for the labour force in a country and the society at large. In this respect the question is of importance to which extent the local communities affected will be able to participate in the benefits created by new technologies and automation.

Intensive dialogue between all stakeholders concerned is suggested with the aim to develop a better understanding of the different positions, opinions and fears. The suggested dialogue could also facilitate the evaluation of different measures currently discussed to address the potential negative consequences of automation and technology for the labour force affected in transport and would include elements such as a robot tax, shorter working periods, initiatives for re-training among others. Such discussions should identify the effects of the mentioned measures and ensure an understanding where those may be helpful and what effects they would create.

3. ESTABLISHING NATIONAL STRATEGIES AND POLICIES TO ADDRESS THE RAMIFICATIONS OF FURTHER AUTOMATION AND TECHNOLOGY IN TRANSPORT

Information from studies and relevant reports, greater levels of awareness and established dialogues between stakeholders and social partners can be the pre-requisite for the formulation of informed policies in countries to set priorities in relation to automation and technology as well strategies to cope with the implications that may result from higher levels of automation and technologies in transport.

Governments may see the need to position countries in the forefront of technological developments and support research and development needed to create and introduce new technologies leading to higher levels of automation in transport. This requires the development of a strategic vision for a country and investments not only in infrastructure, but education as well.

Governments should carefully review to which extent their policies and strategic priorities create incentives for automation to the disadvantage of the labour force. Those that will be affected by negative consequences of more automation and technology certainly wish to be supported in their efforts to cope with the results of technological developments in transport. Re-training on a large scale along with other means of support could be helpful measures to mitigate the potential effects of further automation and technologies in transport.

4. SUPPORTING DEVELOPING COUNTRIES IN COPING WITH THE EFFECTS OF THE INTRODUCTION OF MORE AUTOMATION AND TECHNOLOGY IN TRANSPORT

There is a danger that the divide between developed and developing countries is widening as a result of the further technological development of transport. New technologies in transport will require significant investments in education and infrastructure. Developing countries should be supported in their struggle to master the challenges resulting from the introduction of more technologies and higher levels of automation in transport. To that end, the global community should pledge funding to help developing countries to mitigate the repercussions of innovative technologies and automation.

In this respect, measuring of the trends and developments of automation and technology and benchmarking the stages reached would be an initiative to identify the possible divide between developing and developed countries. Indicators and country profiles suggested in this study may just be the first step to help in illustrating the existing and potentially widening gap.

5. IDENTIFYING ESSENTIAL SKILLS NEEDED TO EFFECTIVELY WORK IN A WORLD OF ADVANCED AUTOMATION AND TECHNOLOGY IN TRANSPORT AND IMPLEMENTING THEM IN EDUCATION AND TRAINING

New skills will be essential to effectively operate new technologies in an increasingly transport system. Identifying these skills at an early stage is key for success of the necessary adaptation process in a country or a transport mode. To adjust existing training and education schemes in order to provide for an early start of new, extended or amended higher education and vocational training programs is another key function in the overall efforts involved to lead the development in respect to more technologies and automation in transport.

It is anticipated that the introduction of automation and technology in transport will trigger the need for a substantial wave of re-training of the labour force in transport on a global scale. As part of a life-long learning process, transport workers need to be prepared to adapt to the changing nature of work and develop new skills and competencies. Examples include digital skills, such as data fluency, digital operation and basic software engineering.

It is important in this respect to understand that training and education require years from the initial idea to a fully developed and introduced program constantly supplying graduates with the required skills and knowledge in a region. Several studies suggest that there will be shortages of suitably qualified personnel in different industry sectors, including transport.

A constant dialogue and a close monitoring of the developing technologies and levels of automation is therefore key in order to ensure that education and training can be adjusted to the needs of the labour market. Governments can facilitate the processes needed through adequate policies and necessary funds.

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APPENDICES

APPENDIX A

COMPARISON OF AUTONOMY SCALES IN DIFFERENT TRANSPORT MODES IN TRANSPORT

TABLE A.1 Comparision between automation scales

Shipping (LR) (Lloyd's Register 2017)	Automation level	Roles of the human / operator	Roles of the system (typically IT system)
AL 0	**No automation**	Manual operation. Performs all actions and decision-making; operator is onboard but may control the vessel remotely, e.g. via radio link	Passive role; presents information and executes operator commands
AL 1	**Onboard decision support**	All actions taken by human operator	Decision support tool presents options and may influence the actions chosen. Data is provided by systems onboard Example(s): RADAR, route planning
AL 2	**Onboard and off-board decision support**	All actions taken by human operator	Decision support tool presents options and may influence the actions chosen. Data is provided by systems onboard or off-board Example(s): Dynamic positioning capability plots, weather routing
AL 3	**'Active' human in the loop**	Decisions and actions are performed with human supervision	System prepares recommendations; actions are performed by the system; data is provided by systems onboard or off-board Example(s): "NAV autopilot", Periodically unattended machinery spaces
AL 4	**Human in the loop, operator/ supervisory**	Supervises systems; has opportunity to intervene and override, in case of high-impact decisions	Decisions and actions are prepared by the system and performed autonomously, once approved by the human operator
AL 5	**Fully autonomous**	Rarely supervises system	Decisions and actions are entirely performed by the system. Alerts operator in case of uncertainty.
AL 6	**Fully autonomous**	No supervision by human; monitoring from a remote control centre	Decisions and actions are entirely performed by the system during the mission

Note: GoA stands for Grade of Automation (rail).

CORRESPONDENCE TO SELECTED SCALES IN TRANSPORT INDUSTRIES					
Aviation (NBAA, 2000)	**Aviation (FAA, 2016)**	**Rail (IAPT, 2013) (IEC, 2009)**	**Automotive (BASt, 2012)**	**Automotive (VDA, 2015)**	**Automotive (SAE, 2016)**
1	Full manual	GoA 0; GoA 1	Driver only	Driver only	No driving automation
2	Manual	GoA 1	Driver only	Driver only	No driving automation
2	Manual	GoA 1	Driver only	Driver only	No driving automation
3	Tactical auto-flight	GoA 2	Assisted	Assisted	Driver assistance; Partial driving automation
4	Full auto-flight	GoA 3	Partially automated	Partly automated	Conditional driving automation
--	Full auto-flight	GoA 3	Highly automated; Fully automated	Highly automated; Fully automated	High driving automation
--	--	GoA 4	--	Driverless	Full driving automation

APPENDIX B

MAIN DATA SOURCES USED IN CHAPTER 2

TABLE B.1 Data sources

Category	Data Source
Air transport	World Bank, Airbus
Railway	World Bank
Road	International Road Federation (IRF)
Maritime	UNCTAD, Institute of Shipping Economics and Logistics (ISL), U.S. Census Bureau, IHS Markit
Imports/Exports	IMF, IHS Markit
Region categories	IMF
Regional modal split	ASEAN StatsDataPortal, Eurostat

Note: Different data sources may use different units of measurement depending on transport mode, including kilometre, mile, nautical mile, kilogram, ton, metric ton, short ton, ton-mile, tonne-mile. Conversions were computed when necessary.

TABLE B.2 Other reference data

Category	Data Source
Modal split in EU	https://ec.europa.eu/eurostat
Modal split in ASEAN	https://www.aseanstats.org/
Supply side: numbers of ships and tonnage of capacities	http://www.imo.org/en/KnowledgeCentre/
Supply side: terminal operators and ports	www.statista.com/UNCTAD
Demand side: international trade statistics	https://comtrade.un.org/ https://www.statista.com/statistics/325934/major-global-marine-terminal-operators/ https://www.wto.org/ https://www.trademap.org/Index.aspx
Demand side: population	https://population.un.org/wpp/ https://esa.un.org/unpd/wpp/Download/Standard/Population/
Demand side: World Input-Output Database	http://www.wiod.org/project
Demand side: commodity categories	http://www.commodities-now.com/reports.html
Performance indicators to strategic objective	http://unctad.org/SearchCenter/Pages/Results.aspx?k=port management series (specific to ports)
Customs Automation **Automated Systems for Customs Data**	http://unctad.org/en/Pages/DTL/TTL/ASYCUDA-Programme.aspx http://www.wcoomd.org/en/topics/enforcement-and-compliance/resources/publications.aspx
Port service productivity and efficiency	www.portopia.eu

APPENDIX C

TABLE C.1 List of labour force data used in Chapter 3

REGION	COUNTRY	YEAR	SOURCE
Africa	Botswana	2009	ILO
	Egypt	2016	ILO
	Ghana	2013	ILO
	Gambia	2012	ILO
	Liberia	2010	ILO
	Madagascar	2012	ILO
	Mali	2015	ILO
	Namibia	2014	ILO
	Sierra Leone	2014	ILO
	Tanzania	2014	ILO
	Uganda	2012	ILO
	Zimbabwe	2011	ILO
Asia and Pacific	Bangladesh	2013	ILO
	Brunei Darussalam	2014	ILO
	Cyprus	2016	ILO
	Fiji	2016	ILO
	Indonesia	2015	ILO
	India	2012	ILO
	Cambodia	2012	ILO
	Sri Lanka	2013	ILO
	Myanmar	2015	ILO
	Mongolia	2016	ILO
	Pakistan	2015	ILO
	Philippines	2016	ILO
	Papua New Guinea	2010	ILO
	Thailand	2015	ILO
	Timor-Leste	2013	ILO
	Turkey	2016	ILO
	Viet Nam	2014	ILO
	Samoa	2012	ILO
	Yemen	2014	ILO

REGION	COUNTRY	YEAR	SOURCE
Europe	Albania	2013	Eurostat
	Austria	2016	Eurostat
	Belgium	2016	Eurostat
	Bulgaria	2016	Eurostat
	Switzerland	2016	Eurostat
	Czechia	2016	Eurostat
	Germany	2016	Eurostat
	Denmark	2016	Eurostat
	Estonia	2016	Eurostat
	Finland	2016	Eurostat
	France	2016	Eurostat
	United Kingdom	2016	Eurostat
	Greece	2016	Eurostat
	Croatia	2016	Eurostat
	Hungary	2016	Eurostat
	Ireland	2016	Eurostat
	Iceland	2016	Eurostat
	Italy	2017	Eurostat
	Lithuania	2016	Eurostat
	Luxembourg	2016	Eurostat
	Latvia	2016	Eurostat
	Macedonia	2016	Eurostat
	Malta	2016	Eurostat
	Netherlands	2016	Eurostat
	Norway	2016	Eurostat
	Poland	2016	Eurostat
	Portugal	2016	Eurostat
	Romania	2016	Eurostat
	Serbia	2017	Eurostat
	Slovakia	2016	Eurostat
	Slovenia	2016	Eurostat
	Sweden	2016	Eurostat

REGION	COUNTRY	YEAR	SOURCE
Latin America and the Caribbean	Brazil	2017	ILO
	Colombia	2015	ILO
	Dominican Republic	2015	ILO
	Ecuador	2017	ILO
	Guatemala	2017	ILO
	Honduras	2014	ILO
	Mexico	2015	ILO
	Nicaragua	2014	ILO
	Peru	2017	ILO
	El Salvador	2015	ILO
	Uruguay	2015	ILO
North America	USA	2016	BLS

Notes: Official Labour Force Survey or equivalent surveys were used. The sources are Eurostat, the International Labour Organization (ILO) and Bureau of Labor Statistics (BLS). The details of the occupational data vary from country to country. Depending on its availability 1-digit or 2-digit occupational codes are used for aggregation purposes.

FIGURE C.1 Age profiles: land transport (source: BLS, ILO, Eurostat)

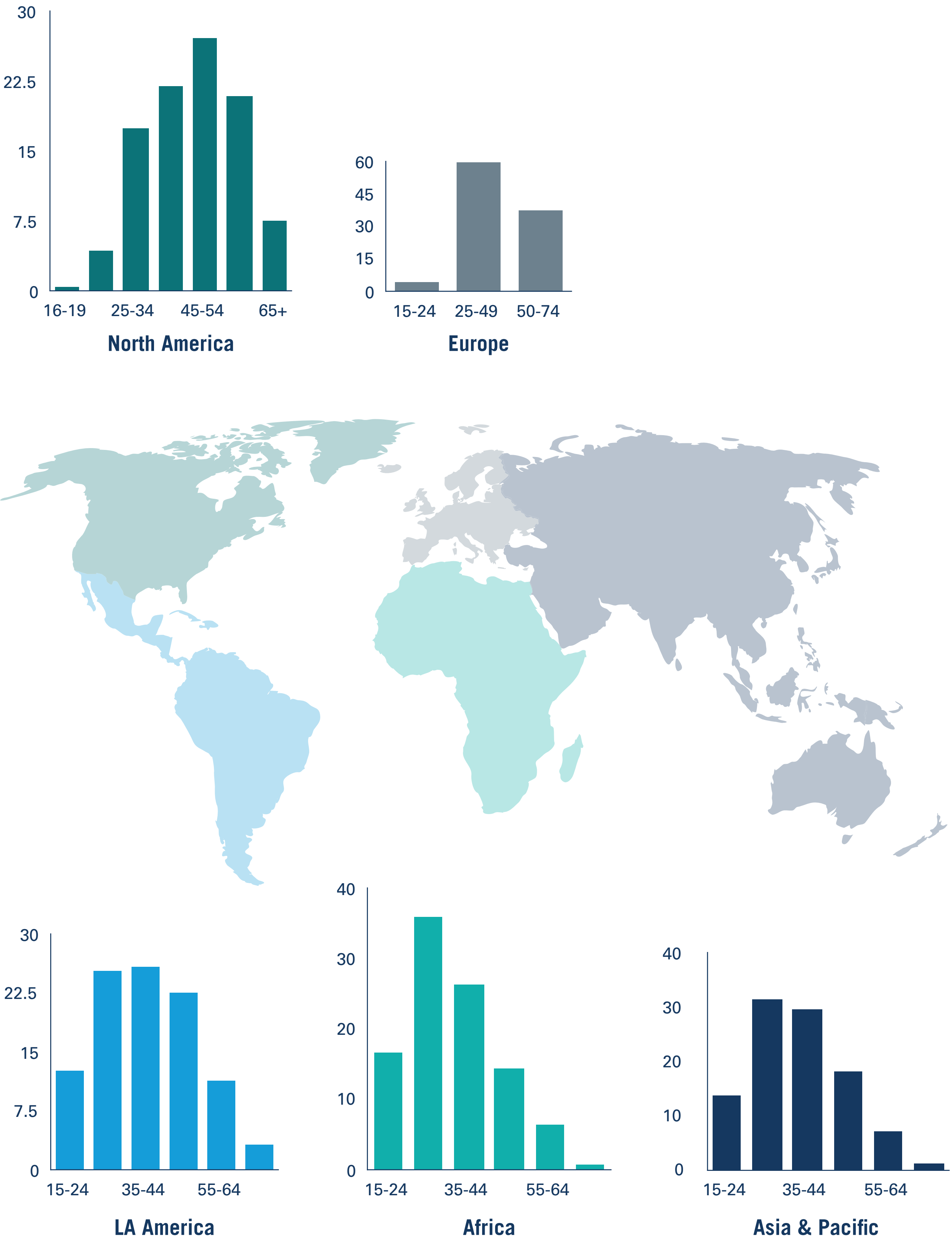


FIGURE C.2 Age profiles: sea transport (sources: BLS, ILO, Eurostat)

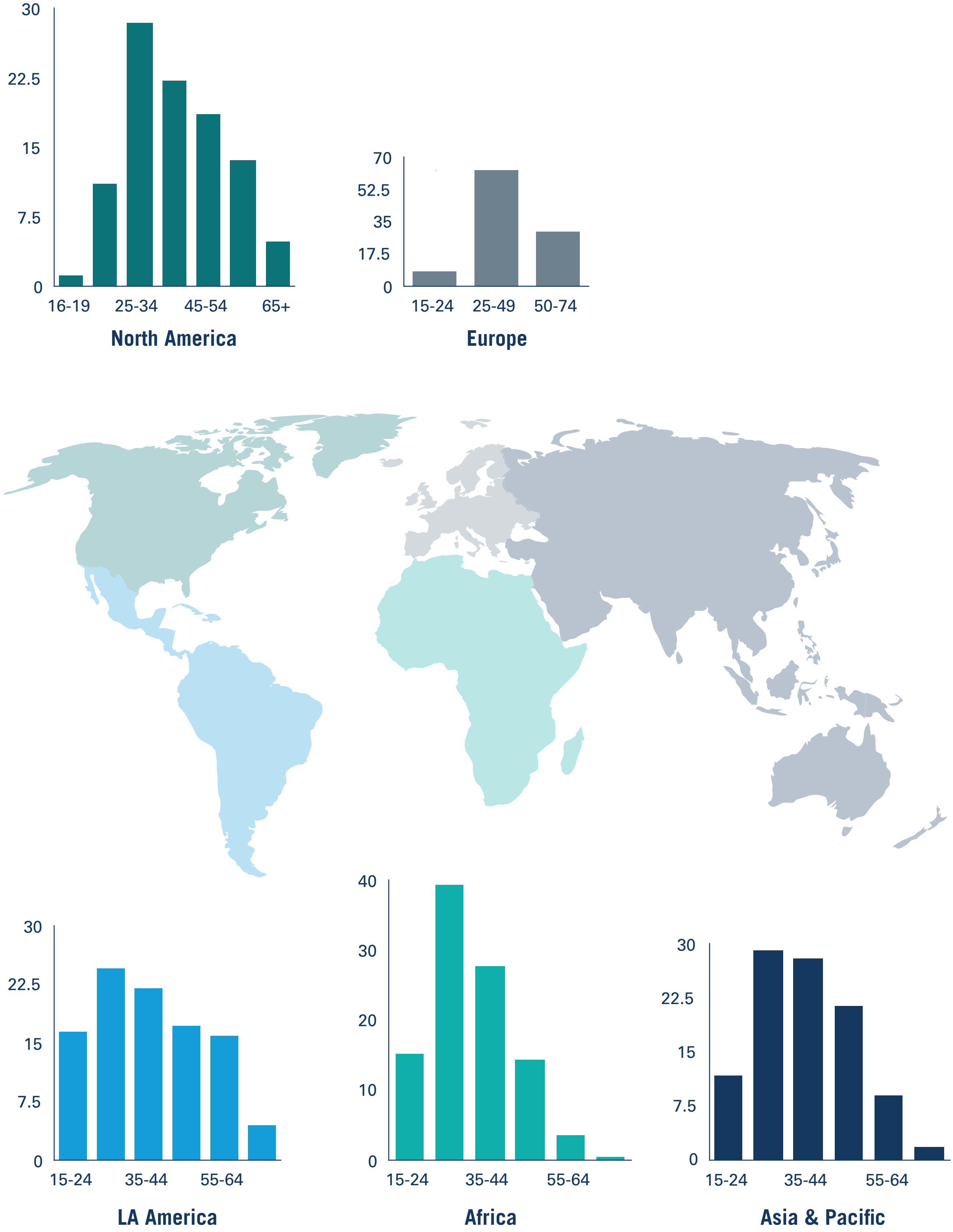
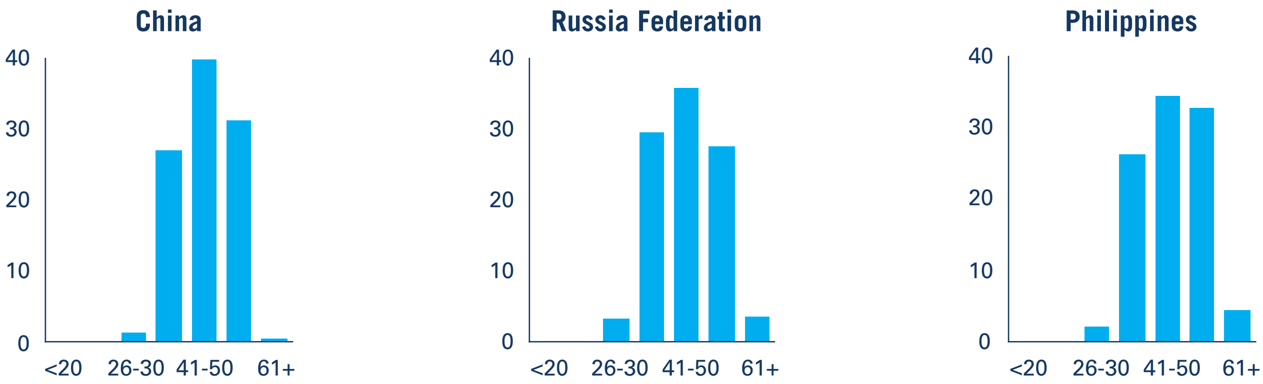


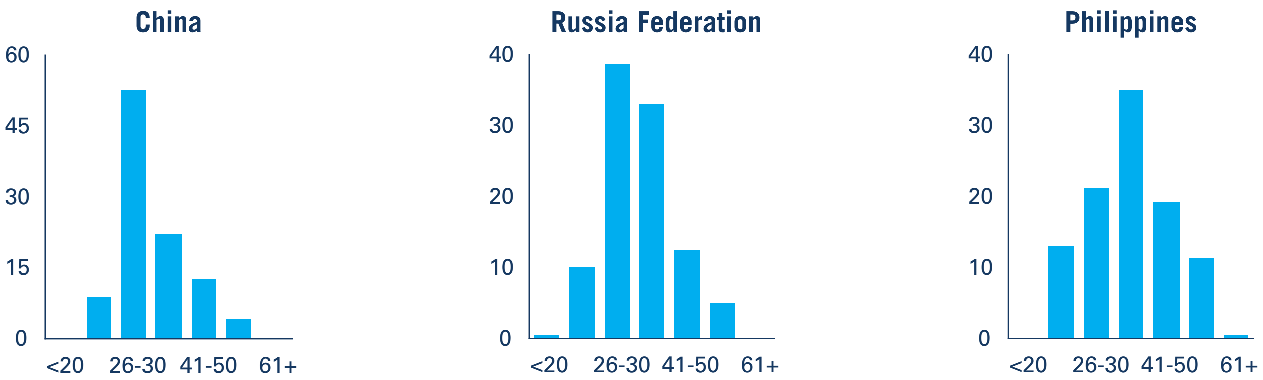
FIGURE C.3 Age profiles: seafarers (ICS/BIMCO, 2016)

OFFICERS

MANAGEMENT LEVEL

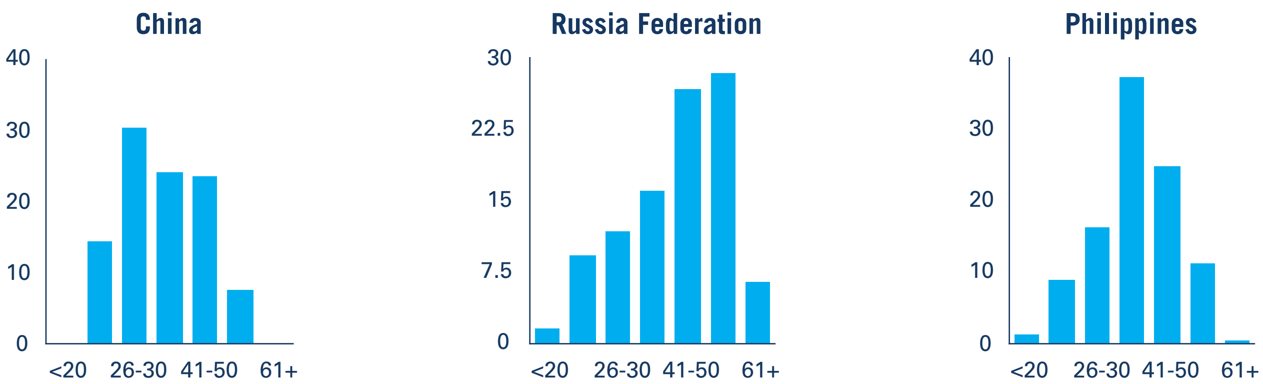


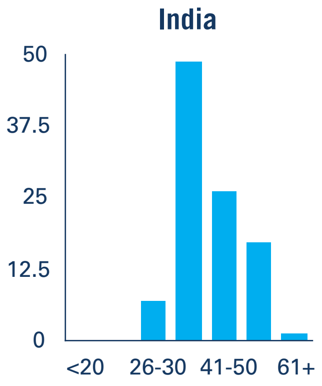
OPERATIONAL LEVEL

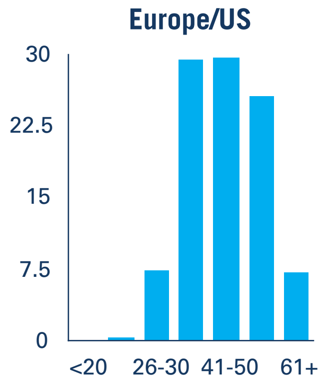


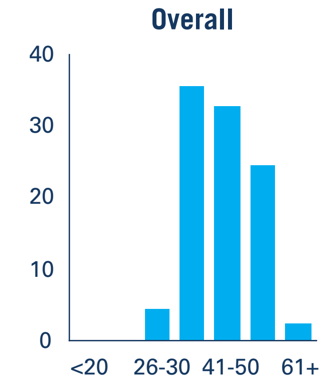
RATINGS

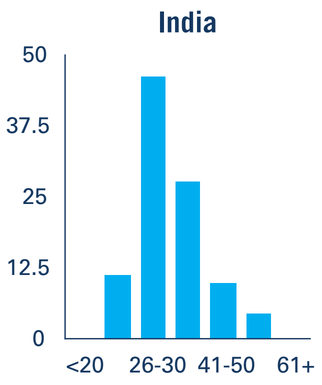
OPERATIONAL LEVEL

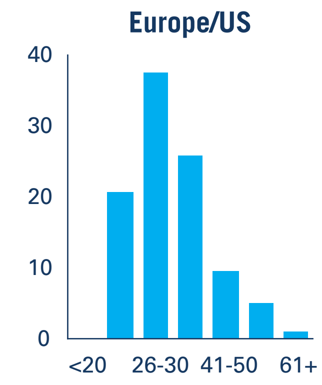


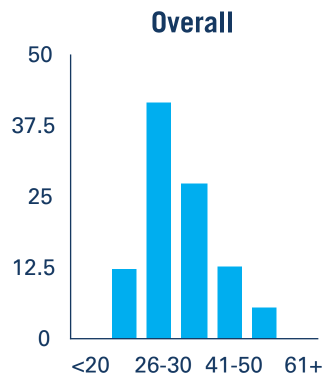

India
50
37.5
25
12.5
0
<20
26-30
41-50
61+

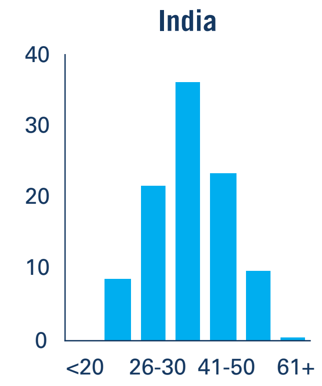

Europe/US
30
22.5
15
7.5
0
<20
26-30
41-50
61+


Overall
40
30
20
10
0
<20
26-30
41-50
61+


India
50
37.5
25
12.5
0
<20
26-30
41-50
61+


Europe/US
40
30
20
10
0
<20
26-30
41-50
61+


Overall
50
37.5
25
12.5
0
<20
26-30
41-50
61+


India
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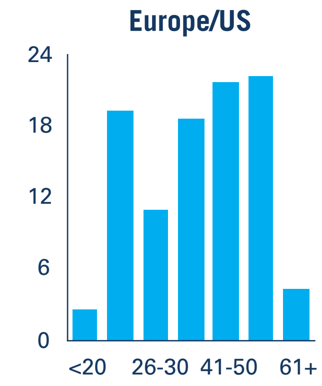
30
20
10
0
<20
26-30
41-50
61+


Europe/US
24
18
12
6
0
<20
26-30
41-50
61+

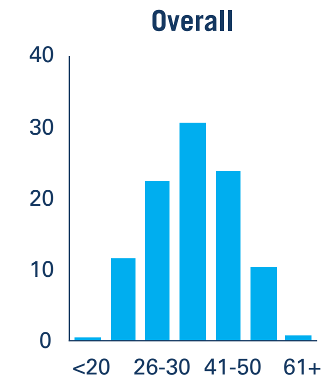

Overall
40
30
20
10
0
<20
26-30
41-50
61+

FIGURE C.4 Age profiles: air transport (sources: BLS, ILO, Eurostat)

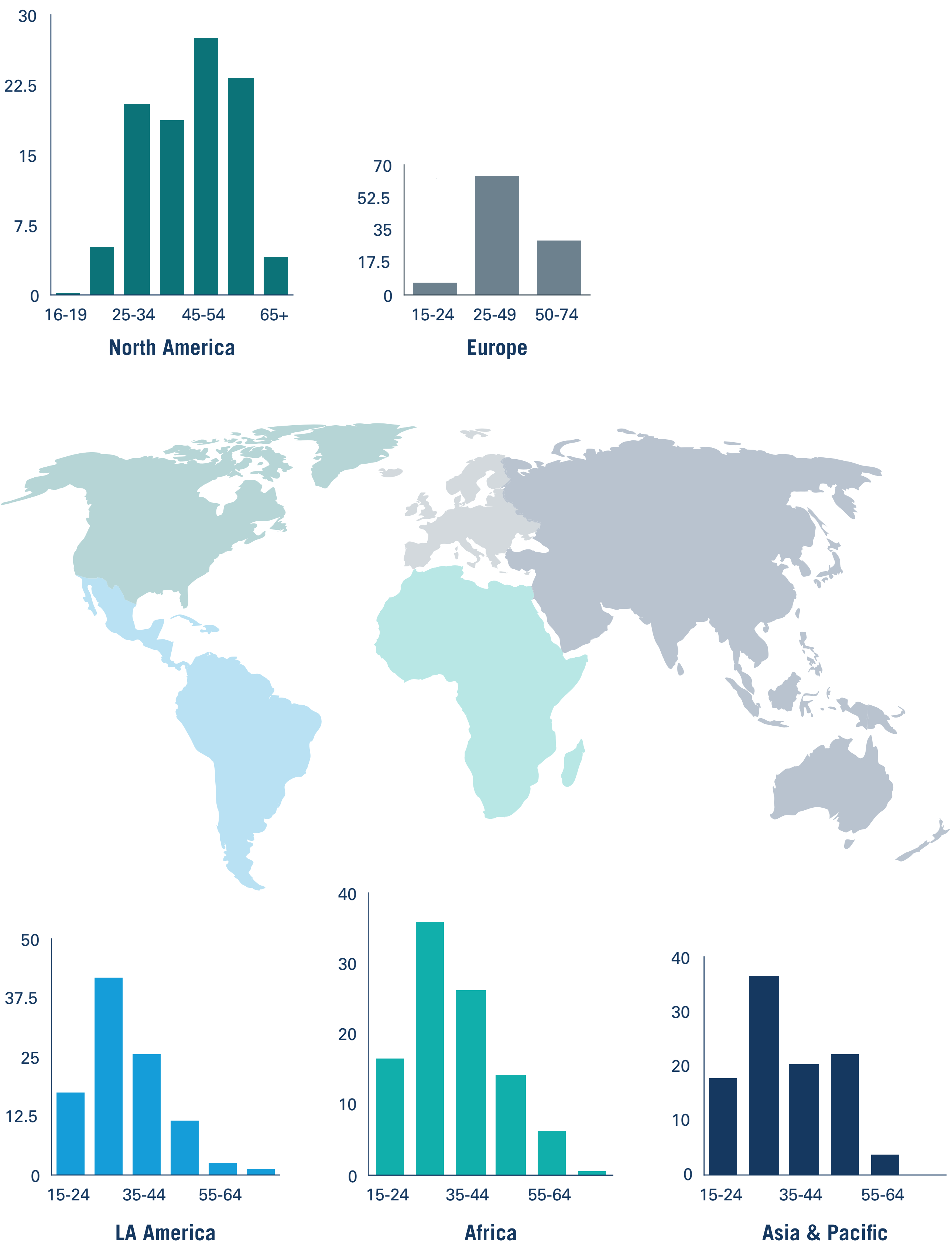
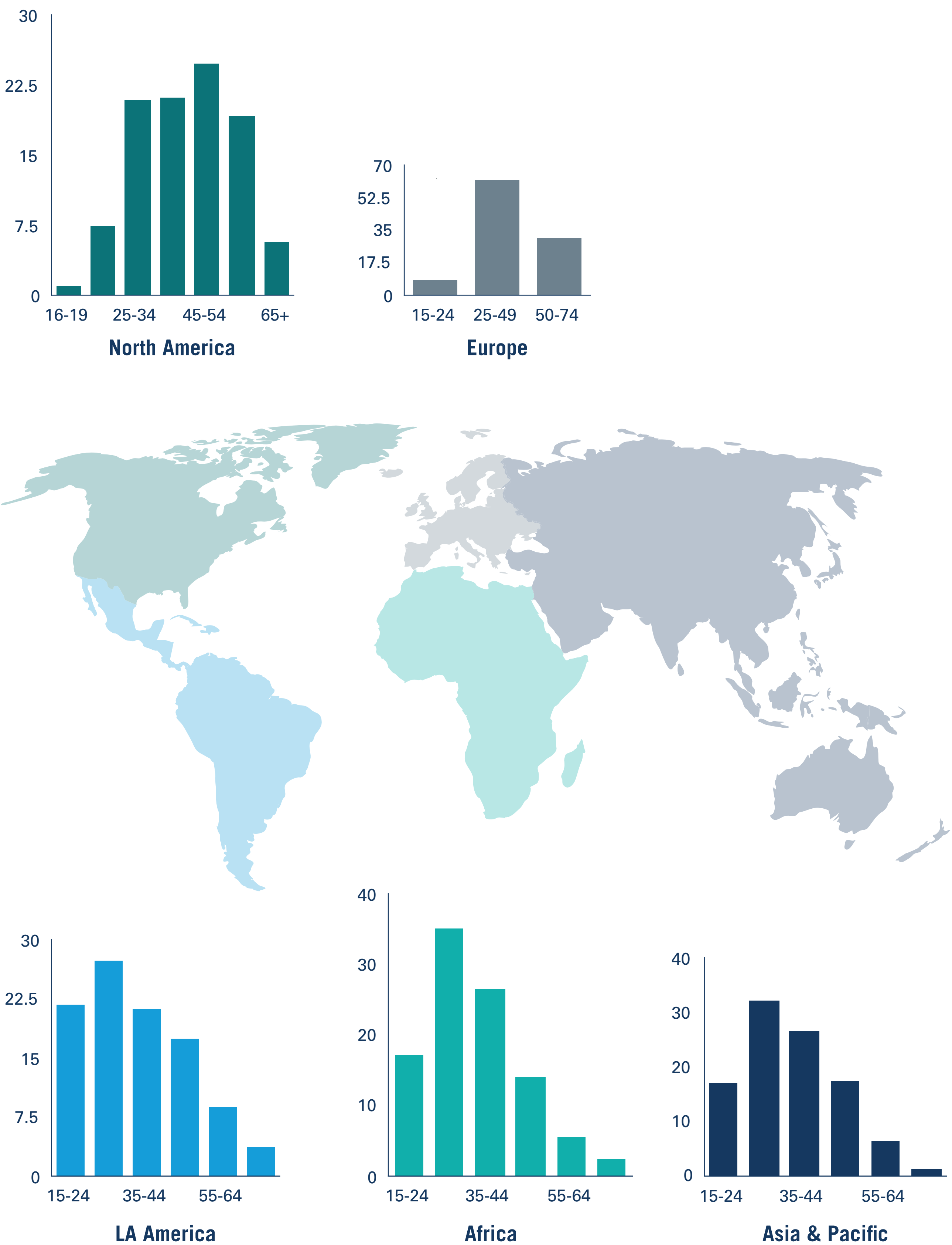


FIGURE C.5 Age profiles: multi-model support (sources: BLS, ILO, Eurostat)



APPENDIX D

EXPLANATIONS OF THE INDICATORS

The data used for the development of this assessment is based on the available data from numerous sources at the time the report was prepared. Some data may be revised further after its publication.

The technical notes and sources describe the sub-indicators used to calculate the principal five key factors applied to assess the country profiles.

These technical notes include the data and sources for both the general and the maritime profile.

GENERAL PROFILE

FACTOR 1: TECHNOLOGY AND INNOVATION

Indicator 1: Technology Platform

Subindicator 1-1: FDI and technology transfer

Unit of measure: 0–10 (best)

Source: World Opinion Forum Executive Opinion Survey: To what extent does FDI bring new technology into your country? World Economic Forum, Executive Opinion Survey, 2016-17. weighted average.

Subindicator 1-2: Firm-level technology absorption

Unit of measure: 0–10 (best)

Source: World Economic Forum Executive Opinion Survey: In your country, to what extent do businesses adopt the latest technologies?, World Economic Forum, Executive Opinion Survey, 2016-17 weighted average.

Subindicator 1-3: LTE mobile network coverage

Percentage of the population covered by at least an LTE/ WiMAX mobile network. Refers to the percentage of inhabitants that live within range of LTE/LTE-Advanced, mobile WiMAX/WirelessMAN, or other more advanced mobile-cellular networks, irrespective of whether or not they are subscribers. This is calculated by dividing the number of inhabitants who are covered by the previously mentioned mobile-cellular technologies by the total population and multiplying by 100. It excludes people covered only by HSPA, UMTS, EVDO and previous 3G technologies, and also excludes fixed WiMAX coverage.

Unit of measure: Percentage of the population

Source: International Telecommunication Union (ITU), 2016

Subindicator 1-4: Internet users

Percentage of individuals who used the Internet from any location and for any purpose, irrespective of the device and network used, in the last three months.

Unit of measure: Percentage of the population

Source: ITU, 2016

Subindicator 1-5: Cybersecurity commitment

Score from the 2017 Global Cybersecurity Index, which measures cybersecurity commitment across five indicators:

- Legal: measures the existence of legal institutions and frameworks related to cybersecurity and cybercrime.
- Technical: measures the existence of technical institutions and frameworks dealing with cybersecurity.
- Organizational: measures the existence of policy coordination institutions and strategies for cybersecurity development at the national level.
- Capacity-building: measures the existence of research and development, education and training programmes; certified professionals and public sector agencies fostering capacity- building.
- Cooperation: measures the existence of partnerships, cooperative frameworks and information- sharing networks.

Unit of measure: 0–10 (best)

Source: International Telecommunication Union (ITU), Global Cybersecurity Index, 2017

Indicator 2: Ability to innovate

Subindicator 2-1: State of cluster development

Unit of measure: 0–10 (best)

Source: World Economic Forum Executive Opinion Survey: In your country, how widespread are well-developed and deep clusters (geographic concentrations of firms, suppliers, producers of related products and services and specialized institutions in a particular field)?, World Economic Forum, Executive Opinion Survey, 2016-17 weighted average.

Subindicator 2-2: Company investment in emerging technology

Unit of measure: 0–10 (best)

Source: World Economic Forum Executive Opinion Survey: In your country, to what extent do companies invest in emerging technologies (e.g. Internet of Things, advanced analytics and artificial intelligence, augmented virtual reality and wearables, advanced robotics, 3D printing)?, World Economic Forum, Executive Opinion Survey, 2017.

Subindicator 2-3: Government procurement of advanced technology

Unit of measure: 0–10 (best)

Source: World Economic Forum Executive Opinion Survey: In your country, to what extent do Government purchasing decisions foster innovations? World Economic Forum, 2017.

Subindicator 2-4: Companies embracing disruptive ideas

Unit of measure: 0–10 (best)

Source: World Economic Forum Executive Opinion Survey: Executive Opinion Survey: In your country, to what extent do companies embrace risky or disruptive business ideas?, World Economic Forum, Executive Opinion Survey, 2916-17 weighted average.

Subindicator 2-5: Patent applications

Total number of patent families filed in at least two of the major five (IP5) patent offices in the world per million people. The major five patent offices are: the European Patent Office. the Japan Patent Office, the Korean Intellectual Property Office, the State Intellectual Property Office of the People's Republic of China and the United States Patent and Trademark Office.

Unit of measure: Number per million people
Source: World Economic Forum calculation based OECD data (patents) and World Bank data (population), 2012-2014 moving average.

Subindicator 2-6: Scientific and technical publications

Number of well-classified scientific and technical journal articles published per billion PPP$ GDP.

Unit of measure: Number per billion PPP$ GDP
Sources: World Economic Forum

FACTOR 2: REGULATIONS AND GOVERNANCE

Indicator 1: Regulation

Subindicator 1-1: Rule of Law

The World Bank develops the Rule of Law dimension in the Worldwide Governance Indicators. It measures to what extent citizens trust in the rules of society, especially the quality of "*contract enforcement, property rights, the police and the courts, as well as the likelihood of crime and violence*" (World Economic Forum / A.T. Kearney, 2018).

Unit of measure: 0-10 (best)
Source: World Bank, Worldwide Governance Indicators, 2016

Subindicator 1-2: Regulatory efficiency

It measures the score of three indicators from the Index of Economic Freedom (World Economic Forum / A.T. Kearney, 2018).

Business Freedom: the degree of efficiency of the regulatory and infrastructure environments for efficient operation of businesses.

Labour Freedom: measures the efficiency of the legal and regulatory framework of a country's labour market and the regulations concerning minimum wages, hiring and employment opportunities in the labour market.

Monetary Freedom: measures price stability with an assessment of price controls.

Unit of measure: 0–10 (best)
Source: World Economic Forum calculation based on the Heritage Foundation data, Index of Economic Freedom, 2017
Indicator 2: Governance

Subindicator 2-1: Incidence of corruption Index

Overall score from the Corruption Perceptions Index (CPI). The incidence of corruption index is based on countries/territories' level of corruption in the country's public sector. The index is developed based on several surveys and assessments of corruption that are collected by a variety of reputable institutions (World Economic Forum / A.T. Kearney, 2018).

Unit of measure: 0–10 (best)
Source: Transparency International, Corruption Perception Index, 2016

Subindicator 2-2: Future orientation of Government

This is arrived at based on the average score of the following four Executive Opinion Survey questions: *1. In your country, how fast is the legal framework adapting to digital business models (e.g. e-commerce, sharing economy, fintech, among others)? (1 = not fast at all; 7 = very fast); 2. In your country, to what extent does the Government ensure a stable policy environment for doing business?; 3. In your country, to what extent does the Government respond effectively to change (e.g. technological changes, societal and demographic trends, security and economic challenges)?; and 4. In your country, to what extent does the Government have a long-term vision in place? For the last three questions, the answer ranges from 1 (not at all) to 7 (to a great extent)"(World Economic Forum / A.T. Kearney, 2018)..*

Unit of measure: 0–10 (best)
Source: World Economic Forum, Executive Opinion Survey, 2017

FACTOR 3 : INFRASTRUCTURE

Indicator 1: Transport infrastructure

The World Economic Forum calculates this indicator by aggregating eight indicators that measure roads, railroads, air transport and water transport infrastructure.

Unit of measure: 0-10 (best)
Source: World Economic Forum, 2017

Indicator 2: Electricity infrastructure

The World Economic Forum calculates this indicator by aggregating two indicators that measure the electrification rate and electric power transmission and distribution losses.

Unit of measure: 0-10 (best)
Source: World Economic Forum, 2017

FACTOR 4: BUSINESS AND INVESTMENT

Indicator 1: Trade

Subindicator 1-1: Trade as a percentage of GDP

The sum of exports and imports of goods and services measured as a share of GDP.

Unit of measure: Percentage of GDP
Source: World Bank, 2016

Subindicator 1-2: Trade tariffs percentage

Trade-weighted average tariff rate. An applied tariff is a customs duty that is levied on imports of merchandise goods. This indicator is calculated as a weighted average of all the applied tariff rates, including preferential rates that a country applies to the rest of the world. The weights are the trade patterns of the importing country's reference group.

Unit of measure: Percentage of duty
Source: International Trade Centre, Trade Competitiveness Map Data, 2016

Subindicator 1-3: Logistics performance

Average score of five components from the International Logistics Performance Index:

Customs: the efficiency of customs and border management clearance.

Ease of arranging shipments: the ease of arranging competitively priced shipments.

Quality of logistics services: the competence and quality of logistics services—trucking, forwarding and customs brokerage.

Tracking and tracing: the ability to track and trace consignments.

Timeliness: the frequency with which shipments reach consignees within scheduled or expected delivery times.

Unit of measure: 0–10 (best)
Source: World Economic Forum
Indicator 2: Investment

Subindicator 1: FDI inflows as a percentage of gross fixed capital formation

Five-year average net FDI flows of country or economy. FDI inflows and outflows comprise capital provided (either directly or through other related enterprises) by a foreign direct investor to an FDI enterprise, or capital received by a foreign direct investor from a FDI enterprise. Data on FDI flows are presented on net bases (capital transactions' credits less debits between direct investors and their foreign affiliates).

Unit of measure: US$ millions
Source: UNCTAD, 2012–16 moving average

FACTOR 5: HUMAN CAPITAL AND SKILLS

Indicator 1: Current Labour Force

Subindicator 1-1: Manufacturing employment

Manufacturing employment refers to employment in sectors of economic activity whose definitions are based on ISIC, Revision 3 (1990) and Revision 4 (2008). Manufacturing refers to industries belonging to sector D defined by ISIC Revision 3, or C defined by ISIC Revision 4.

Unit of measure: Percentage of working population
Sources: World Economic Forum based on UNIDO and ILO.

Subindicator 1-2: Knowledge intensive employment

Sum of people included in categories 1 to 3 as a percentage of total people employed, according to the ISCO. The categories are classified as follows:

ISCO-08:1. Managers; 2. Professionals; and 3. Technicians and associate professionals (years 2007-15).

ISCO-88: 1. Legislators, senior officials and managers; 2. Professionals; and 3. Technicians and associate professionals (2007-15). ISCO-68: 1. Professional, technical and related workers (category 0 Armed forces is excluded); 2. Administrative and managerial workers; and 3. Clerical and related workers (years 2007-08).

Unit of measure: Percentage of working population
Sources: World Economic Forum based on the ILO.

Subindicator 1-3: Female participation in the labour force

The ratio of the percentage of women aged 15-64 participating in the labour force as workers earning wages and salaries to the percentage of men aged 15-64 participating in the labour force as workers earning wages and salaries.

Unit of measure: Ratio
Source: World Economic Forum calculation based on the ILO.

Subindicator 1-4: Mean years of schooling

Average number of completed years of education of a country's population aged 25 years and older.

Unit of measure: Years
Source: World Economic Forum based on the United Nations Educational, Scientific and Cultural Organization (UNESCO).

Subindicator 1-5: Availability of scientists and engineers

See World Economic Forum Executive Opinion Survey: *In your country, to what extent are scientists and engineers available?* (1=not available at all, 7= widely available).

Unit of measure: 0-10 (best)
Source: World Economic Forum Executive Opinion Survey, 2016-2017 weighted average

Subindicator 1-6: Digital skills among the population

Unit measure: 0-10 (best)
Source: World Economic Forum Executive Opinion Survey: *In your country, to what extent does the active population possess sufficient digital skills (e.g. computer skills, basic coding, and digital reading)?*, World Economic Forum, 2016-2017.

Indicator 2: Future labour force

Subindicator 1-2: Country capacity to attract and retain talent

Calculation made by the World Economic Forum based on two of their surveys: *To what extent does your country attract talented people from aboard?* and *To what extent does your country retain talented people?*.

Unit measure: 0-10 (best)
Source: World Economic Forum, Executive Opinion Survey, 2016-2017 weighted average.

Subindicator 2-2: Active labour policies

Unit measure: 0-10 (best)
Source: World Economic Forum Executive Opinion Survey*: In your country, to what extent are unemployed people supported in reskilling and finding new employment?*, World Economic Forum, Executive Opinion Survey, 2016-2017 weighted average.

MARITIME PROFILE

FACTOR 1: TECHNOLOGY AND INNOVATION

Indicator 1: Exports of ships as a share of total exports (exported value in 2016)

Unit of measure: percentage of ships to total exports (deciles)
Source: Calculation made by the WMU based on data from the Clarkson Research Centre

Indicator 2: Average age fleet (the lower the better)

Unit of measure: years
Source: Calculation made by the WMU based on data from the Clarkson Research Centre

Indicator 3: Maritime/Marine engineering universities

Unit of measure: 0-10 (best)
Source: Shanghai ranking universities

FACTOR 2: REGULATION AND GOVERNANCE

Indicator 1: Contribution to discussion about maritime autonomous surface ships at the IMO

It is a composite indicator comprising the attendance of a country in the MASS working group related to the IMO MSC 100 session, the interventions during the working group, the submission of documents to maritime safety committee related to MASS (related to IMO MSC 100 session) and volunteering to review relevant IMO instruments.

Unit of measure: 0 (not active)-10 (very active)
Source: WMU

Indicator 2: Ratification of the relevant IMO instruments

Unit of measure: Number of conventions ratified
Source: IMO

Indicator 3: IACS and non-IACS classification societies

Unit of measure: Number of IACS and non-IACS classification societies.
Source: IMO maritime profile

FACTOR 3: INFRASTRUCTURE

Indicator 1: Quality of port

Based on the World Economic Forum Executive Opinion Survey: *In your country, what is the quality (extent and condition) of seaports (if yours is a landlocked country, please assess your access to seaports)?*

Unit of measure: 0-10 (best)
Source: World Economic Forum Executive Opinion Survey (2017-2018)

Indicator 2: Quality of liner shipping connectivity

Unit measure: 0-10 (best)
Source: Clarkson Research Centre

FACTOR 4: BUSINESS AND INVESTMENT

Indicator 1: Container port throughput per GDP (2016)

Unit of measure: TEU per USD (PPP)
Source: UNCTAD

Indicator 2: Number of ships bought (2014-2016)

Unit of measure: Number of ships
Source: UNCTAD

Indicator 3: Merchant fleet by country of beneficial ownership

Scale: Deadweight tonnes (deciles)
Source: Clarkson Research Centre

FACTOR 5: HUMAN CAPITAL AND SKILLS 0-10

Indicator 1: Total number of seafarers

Unit measure: Number of seafarers
Source: ICS/BIMCO (2015)

Indicator 2: Ratio of officers to total seafarers

Unit measure: 0-10 (best)
Source: ICS/BIMCO (2015)

REGIONAL AND INCOME CLASSIFICATIONS USED IN THE REPORT.

TABLE D.1 Regional classification of the selected countries

The following regional classification was used for analysis in the report.

AFRICA	AMERICA	EAST ASIA AND THE PACIFIC	EUROPE	MIDDLE EAST
Ghana Nigeria South Africa	Brazil Panama Peru U.S.A	Australia China Japan Philippines Republic of Korea	Denmark France Norway Sweden	Turkey

TABLE D.2 World Bank classification by income level (2018)

The following classifications of monthly incomes by country were used for analysis in the report

LOW INCOME ($ 1,005 OR LESS)	LOWER-MIDDLE INCOME ($ 1,006 -3,955)	UPPER-MIDDLE INCOME ($ 3,955-12,235)	HIGH INCOME ($ 12,236 OR MORE)
-	Ghana Nigeria Philippines	Brazil Panama Peru South Africa Turkey	Australia China Denmark France Japan Republic of Korea Sweden

DETAILED COUNTRY PROFILES

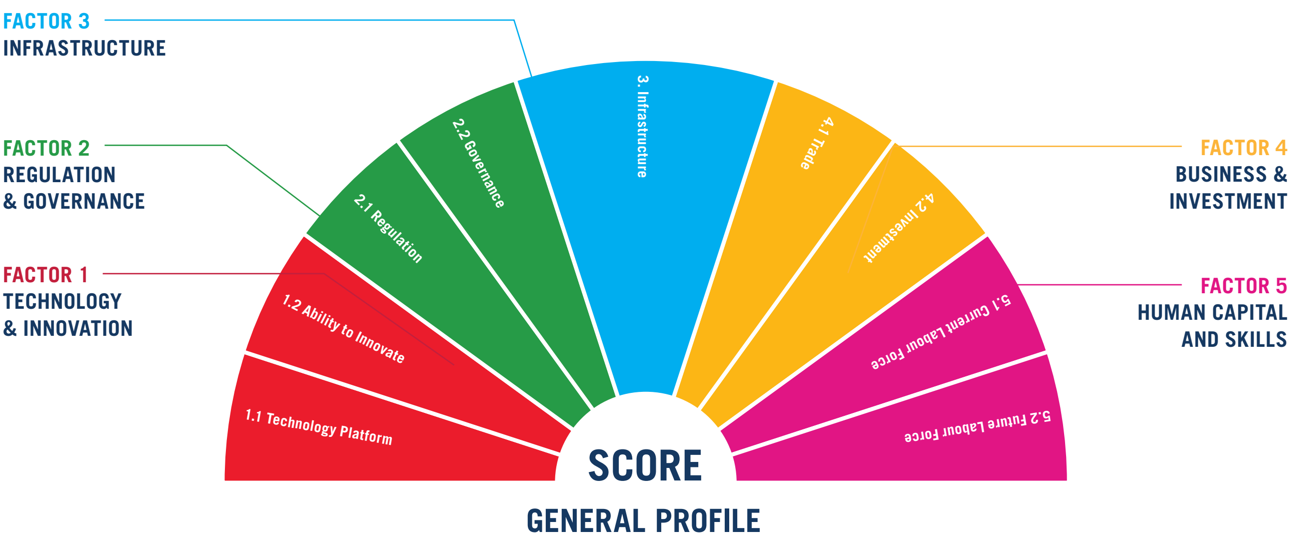
COUNTRY PROFILES

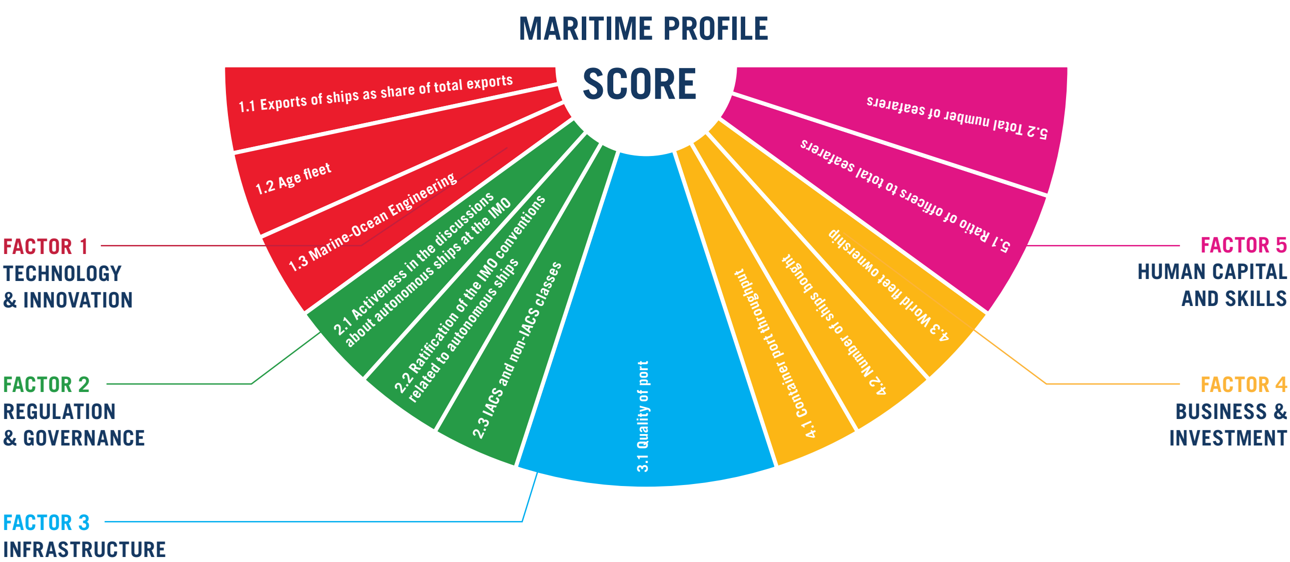
Today, the maritime sector is experiencing a historical transformation with the step-by -step integration of new and emerging technologies. Several countries around the world are participating in this transformation. Others are receiving technology transfers and might participate in this transformation in the future. Policy makers in the maritime field have an interest in identifying the pace and level of the introduction of new technologies in order to develop future strategies, including the preparation of the workforce and the skills and expertise that they will require.

To assist policy makers in determining these future strategies, the WMU has developed a framework for country profiling, and tested this method using 17 countries in respect of their adoption of new and emerging technologies in the maritime field.

Each Country Profile consists of three sections:

- **Basic data:** Composed of key general data and key maritime information.
- **General profile:** composed of performance indicators related to the adoption of new technologies.
- **Maritime profile:** composed of performance factors related to the adoption of new technologies specific to the maritime field.

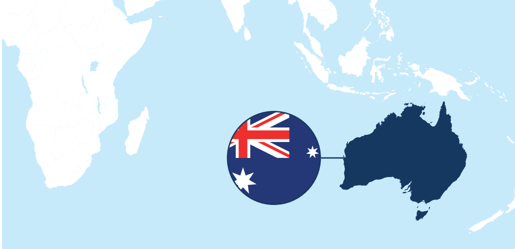




COUNTRY PROFILE

TECHNOLOGY READINESS: MARITIME

AUSTRALIA



KEY MARITIME INFORMATION FOR 2017

POPULATION (2017)
24.3 MILLION

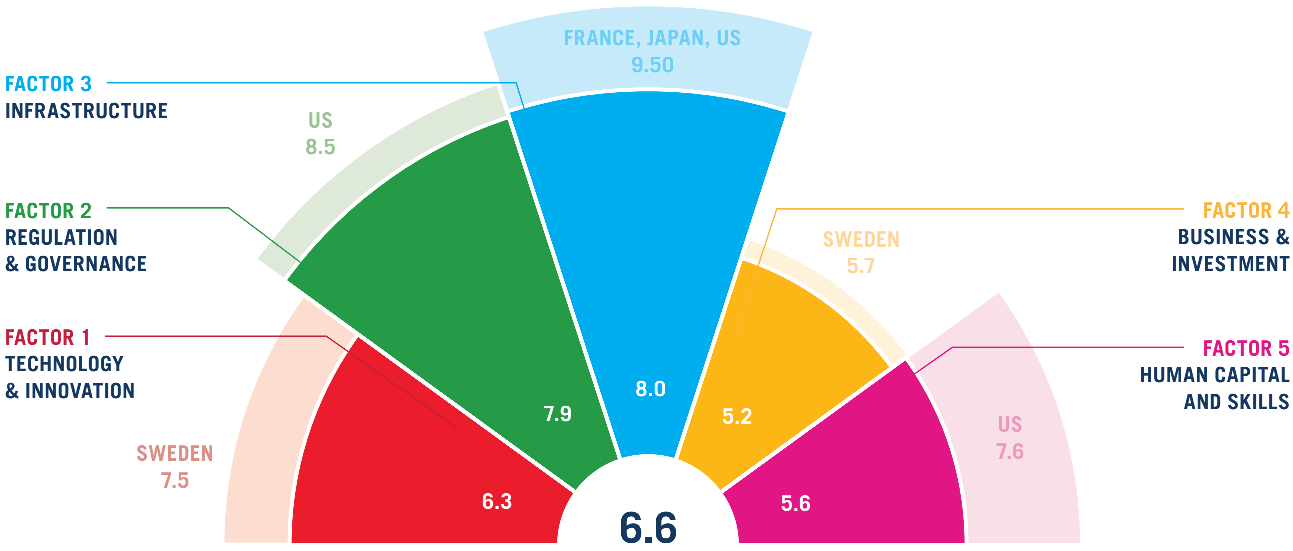
MERCHANDISE TRADE (US$)
388,470 MILLION

FLEET OWNERSHIP (DWT)
2,355 THOUSANDS

GDP US$ (2017)
1,259.0 BILLION

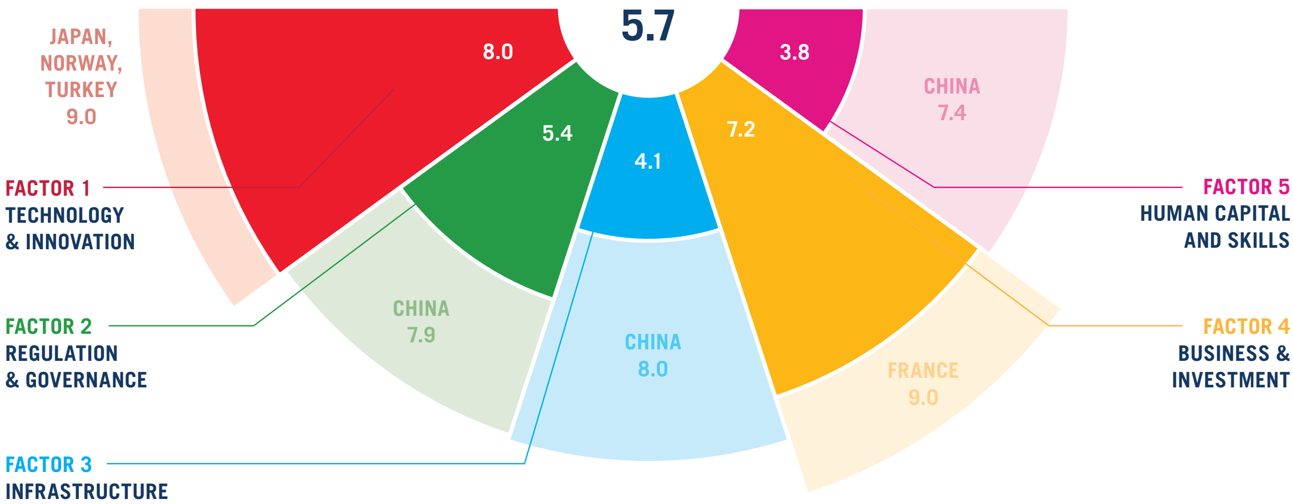
FLEET-NATIONAL FLAG (DWT)
1,907 THOUSANDS

SHIP BUILDING (GT)
..



GENERAL PROFILE

MARITIME PROFILE



COUNTRY PROFILE

TECHNOLOGY READINESS: MARITIME

BRAZIL

KEY MARITIME INFORMATION FOR 2017

POPULATION (2017)
206.1 MILLION

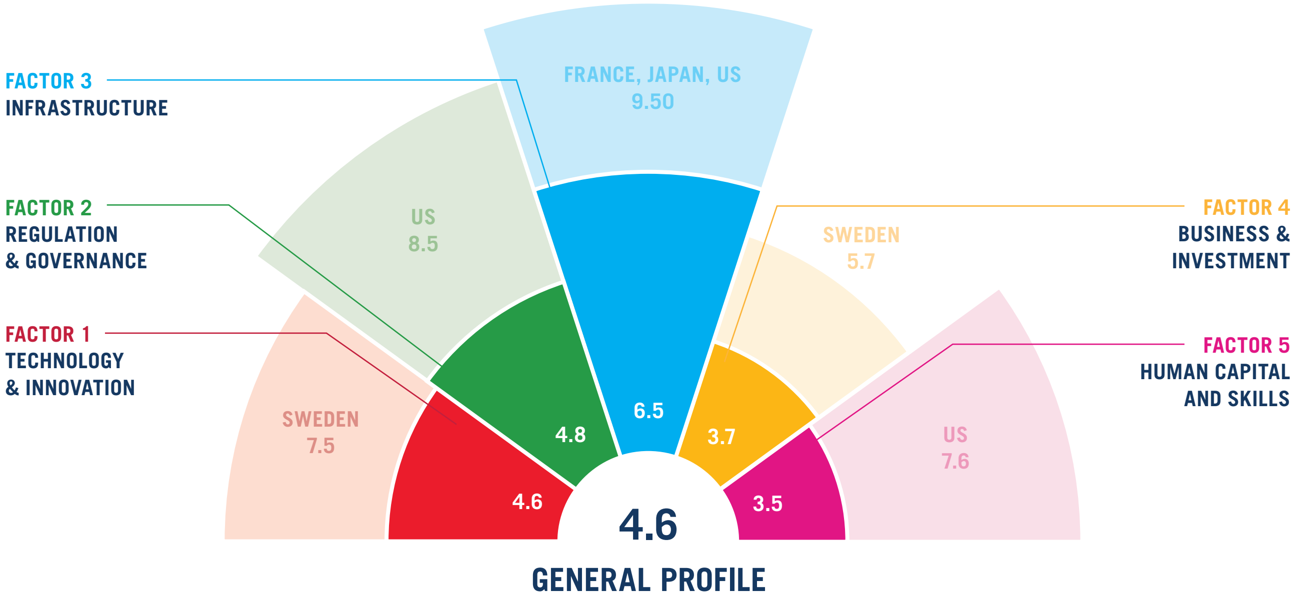
MERCHANDISE TRADE (US$)
328,778 MILLION

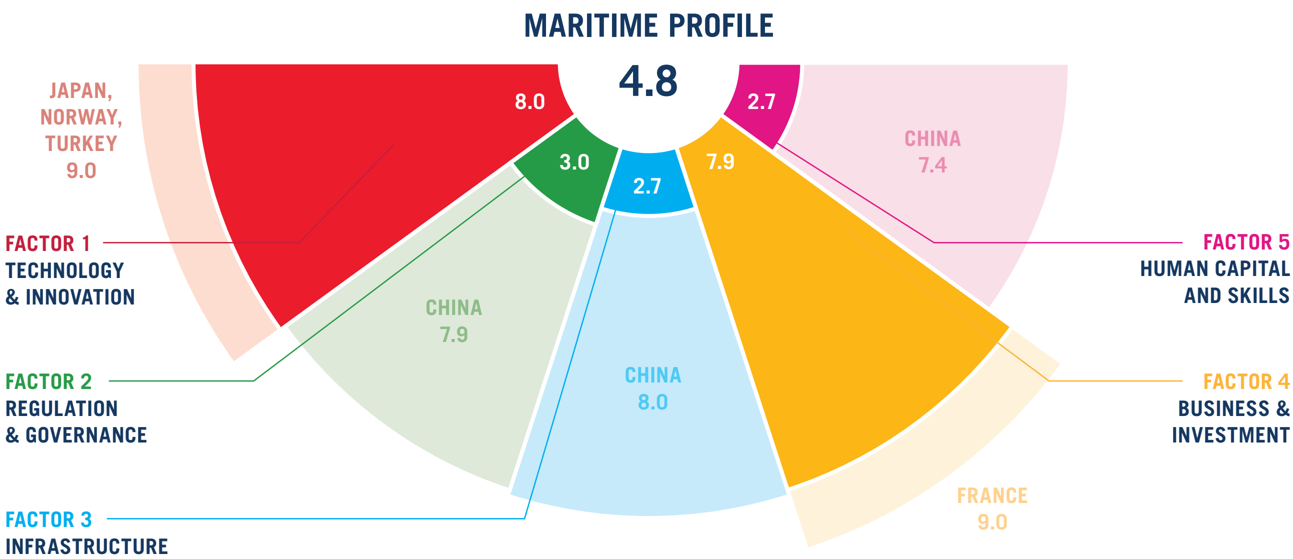
FLEET OWNERSHIP (DWT)
15,783 THOUSANDS

GDP US$ (2017)
1,798.6 BILLION

FLEET-NATIONAL FLAG (DWT)
4,347 THOUSANDS

SHIP BUILDING (GT)
218,764





COUNTRY PROFILE

TECHNOLOGY READINESS: MARITIME

CHINA

KEY MARITIME INFORMATION FOR 2017

POPULATION (2017)
1,382.7 MILLION

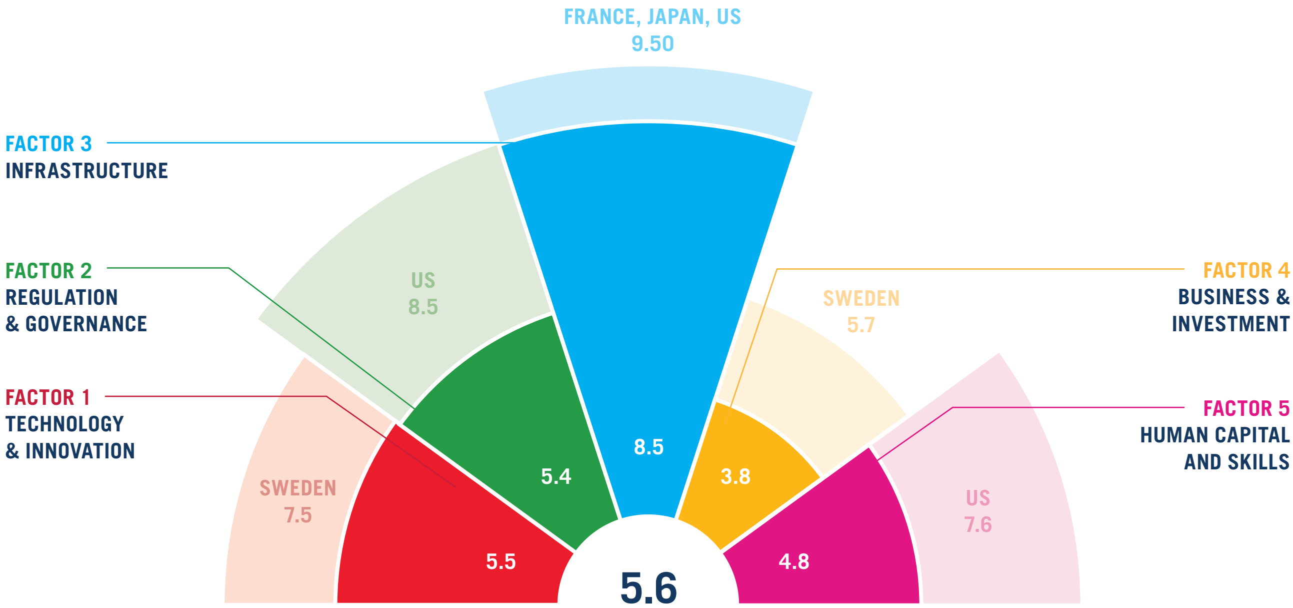
MERCHANDISE TRADE (US$)
3,685,557 MILLION

FLEET OWNERSHIP (DWT)
158,884 THOUSANDS

GDP US$ (2017)
11,218.3 BILLION

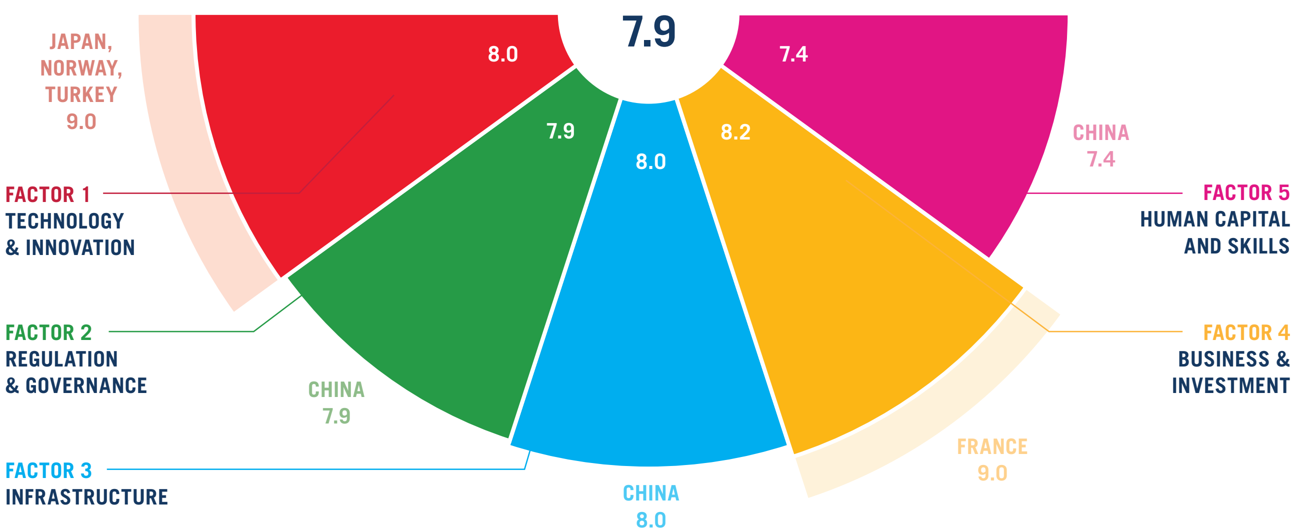
FLEET-NATIONAL FLAG (DWT)
76,200 THOUSANDS

SHIP BUILDING (GT)
22,178,672



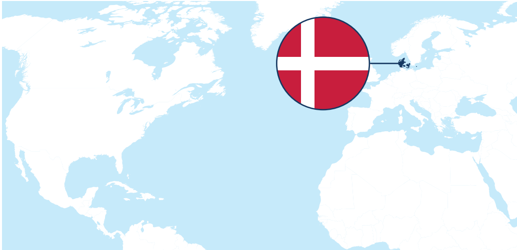
GENERAL PROFILE

MARITIME PROFILE



COUNTRY PROFILE

TECHNOLOGY READINESS: MARITIME



DENMARK

KEY MARITIME INFORMATION FOR 2017

POPULATION (2017)
5.7 MILLION

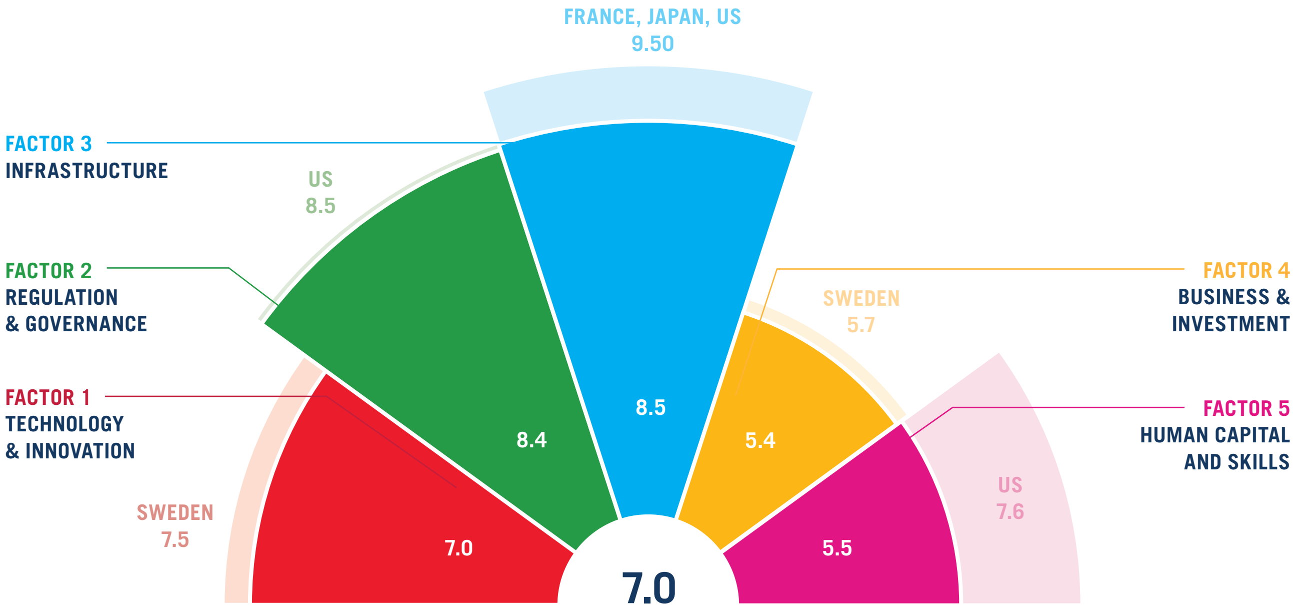
MERCHANDISE TRADE (US$)
180,899 MILLION

FLEET OWNERSHIP (DWT)
38,315 THOUSANDS

GDP US$ (2017)
306.7 BILLION

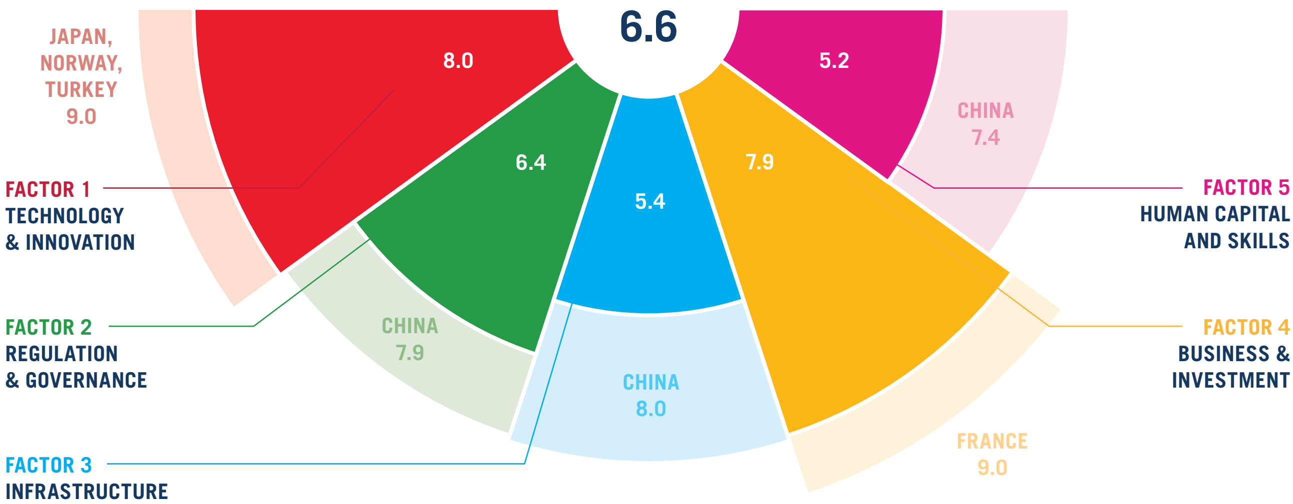
FLEET-NATIONAL FLAG (DWT)
17,154 THOUSANDS

SHIP BUILDING (GT)
24,937



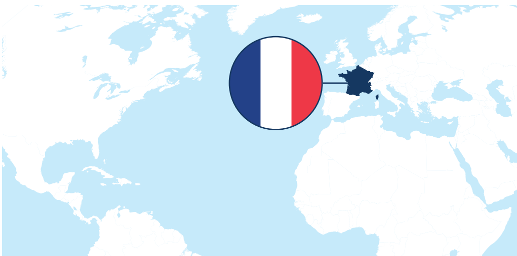
GENERAL PROFILE

MARITIME PROFILE



COUNTRY PROFILE

TECHNOLOGY READINESS: MARITIME



FRANCE

KEY MARITIME INFORMATION FOR 2017

POPULATION (2017)
64.6 MILLION

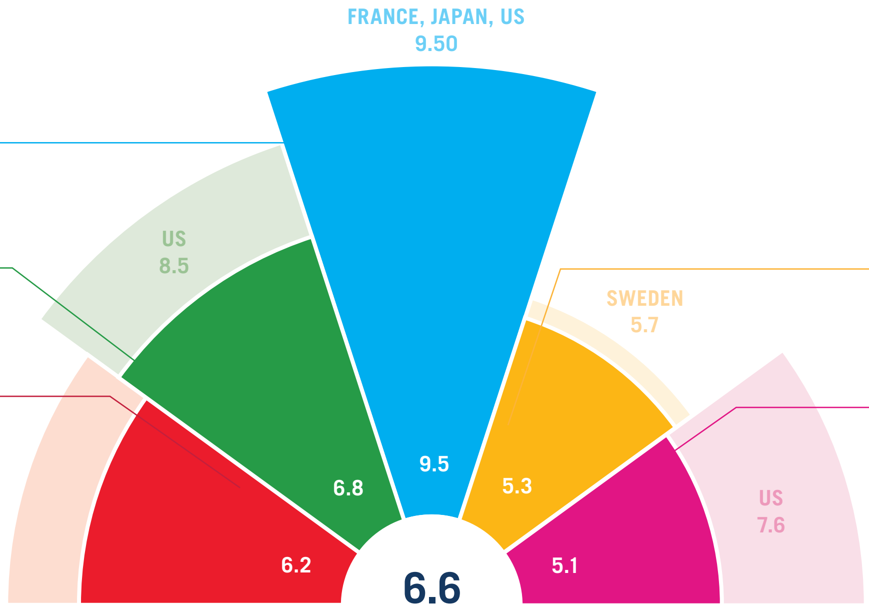
MERCHANDISE TRADE (US$)
1,073,998 MILLION

FLEET OWNERSHIP (DWT)
42,084 THOUSANDS

GDP US$ (2017)
2,463.2 BILLION

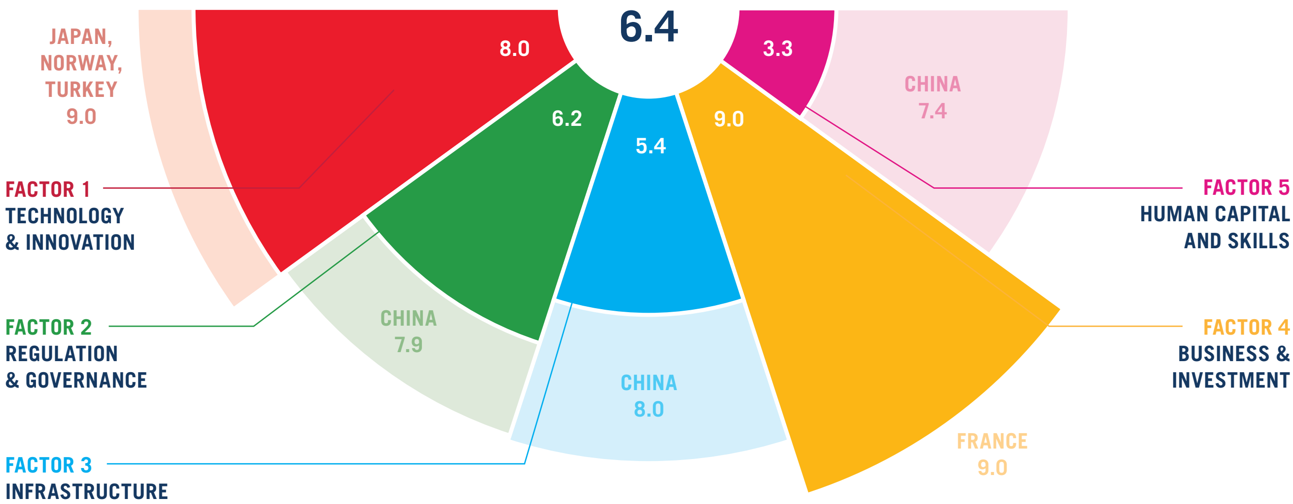
FLEET-NATIONAL FLAG (DWT)
6,905 THOUSANDS

SHIP BUILDING (GT)
227,867



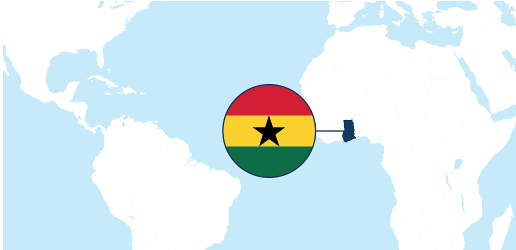
GENERAL PROFILE

MARITIME PROFILE



COUNTRY PROFILE

TECHNOLOGY READINESS: MARITIME



GHANA

KEY MARITIME INFORMATION FOR 2017

POPULATION (2017)
27.6 MILLION

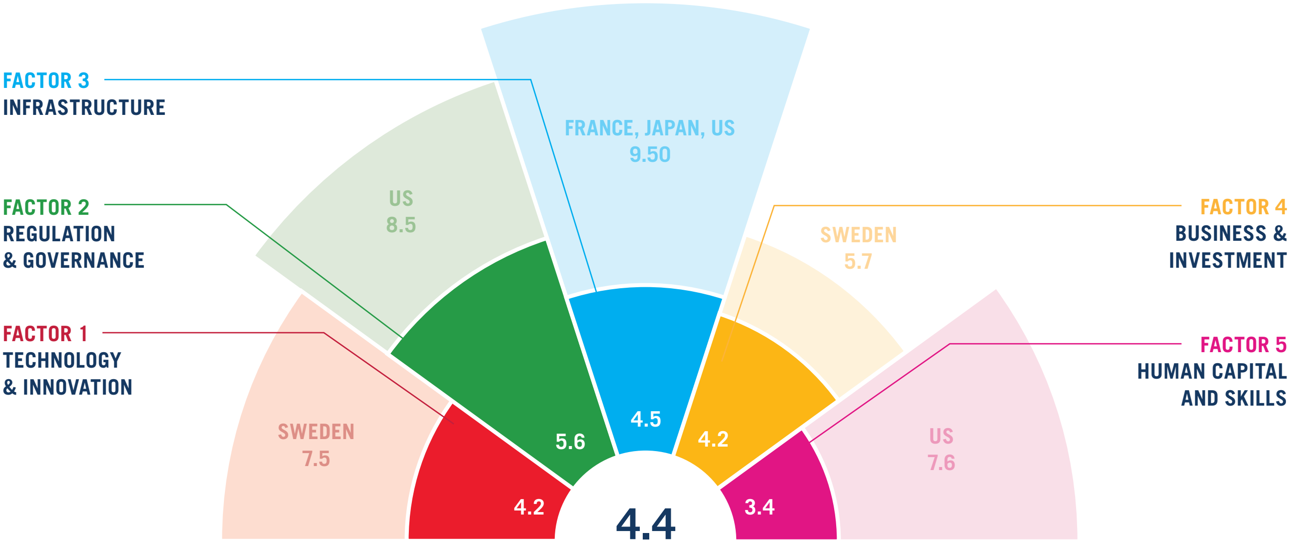
MERCHANDISE TRADE (US$)
24,044 MILLION

FLEET OWNERSHIP (DWT)
27 THOUSANDS

GDP US$ (2017)
43.3 BILLION

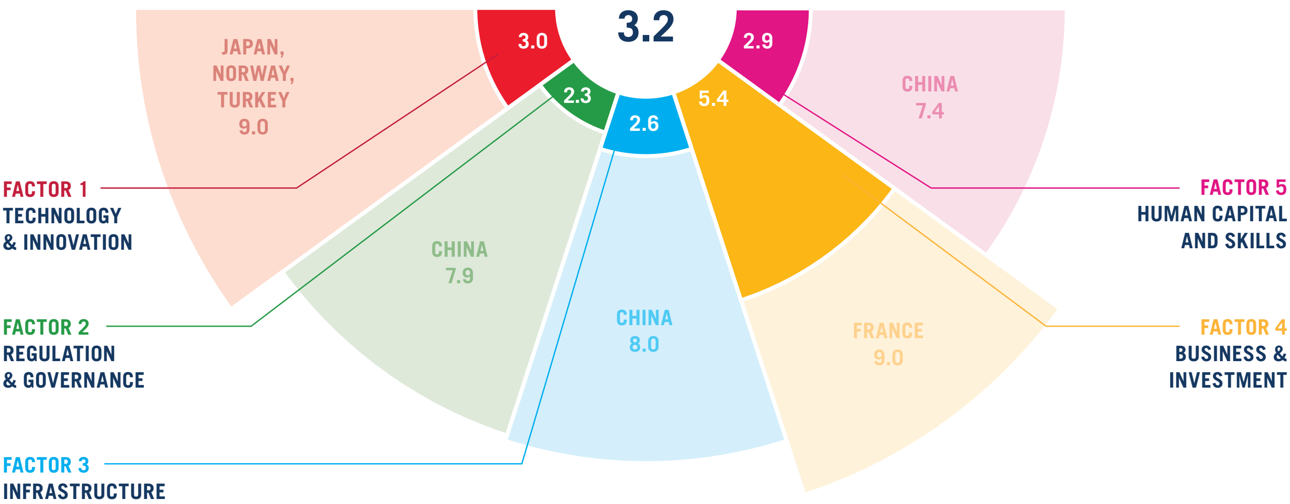
FLEET-NATIONAL FLAG (DWT)
33 THOUSANDS

SHIP BUILDING (GT)
..



GENERAL PROFILE

MARITIME PROFILE



COUNTRY PROFILE
TECHNOLOGY READINESS: MARITIME

JAPAN

KEY MARITIME INFORMATION FOR 2017

POPULATION (2017)
126.9 MILLION

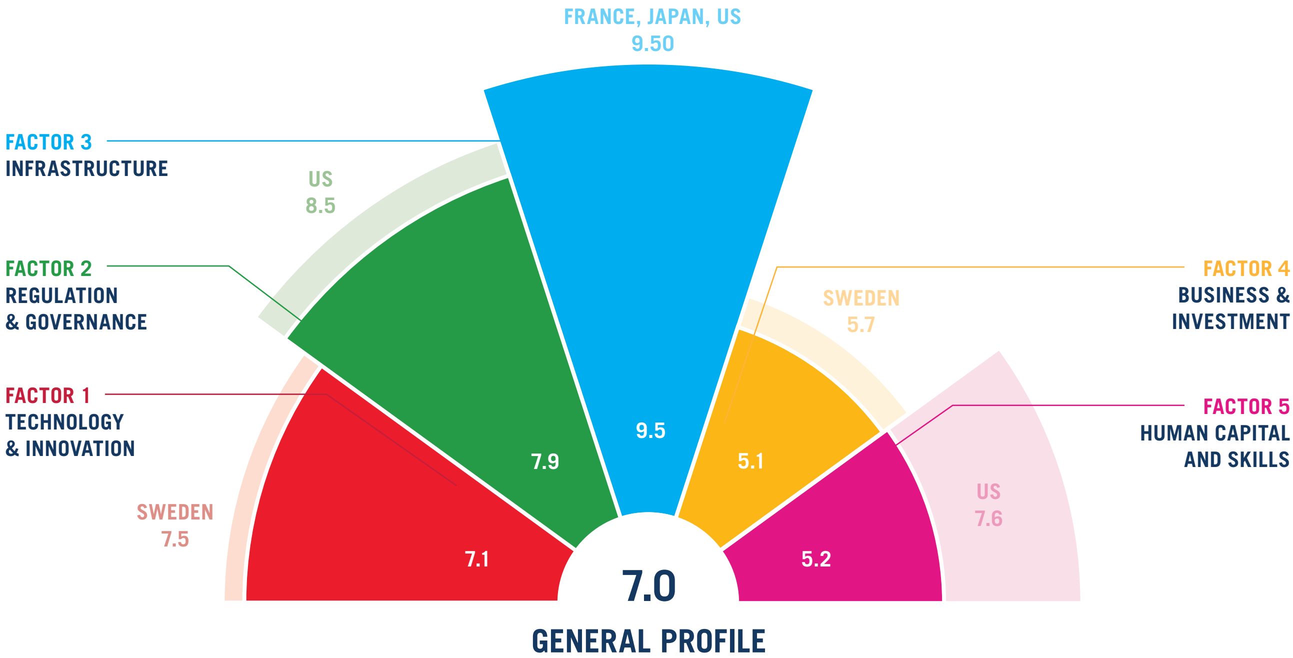
MERCHANDISE TRADE (US$)
1,252,502 MILLION

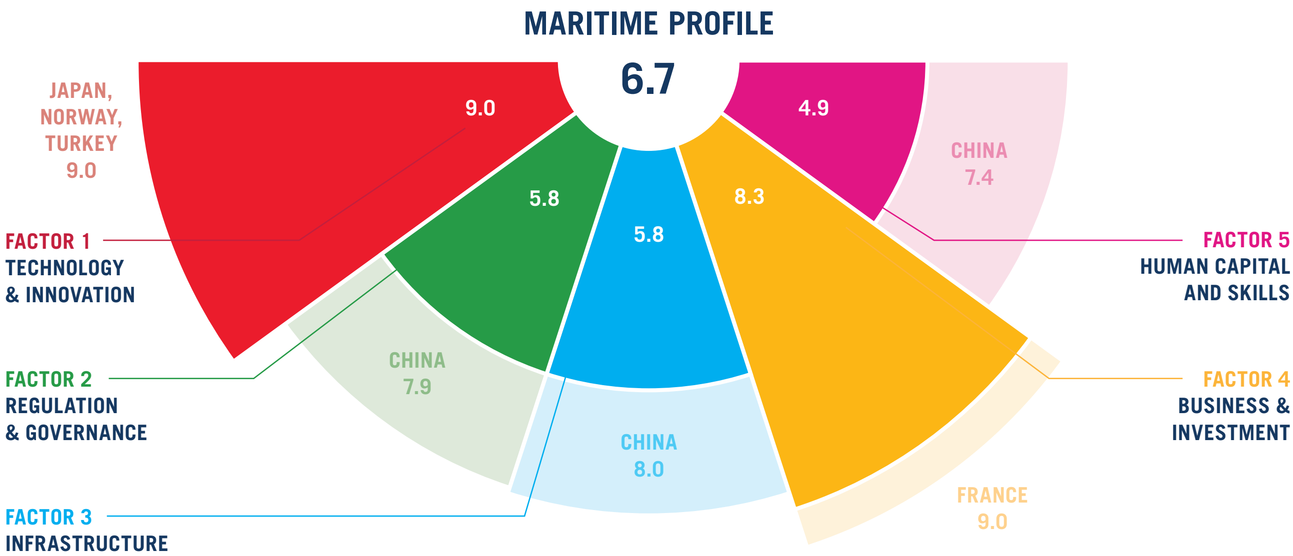
FLEET OWNERSHIP (DWT)
228,980 THOUSANDS

GDP US$ (2017)
4,938.6 BILLION

FLEET-NATIONAL FLAG (DWT)
32,274 THOUSANDS

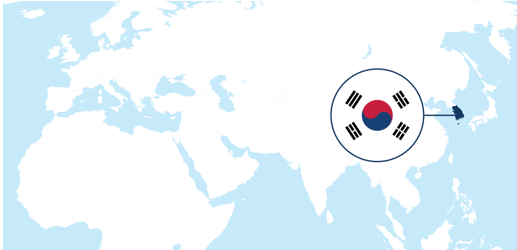
SHIP BUILDING (GT)
13,348,773





COUNTRY PROFILE

TECHNOLOGY READINESS: MARITIME



KOREA, REP.

KEY MARITIME INFORMATION FOR 2017

POPULATION (2017)
51.2 MILLION

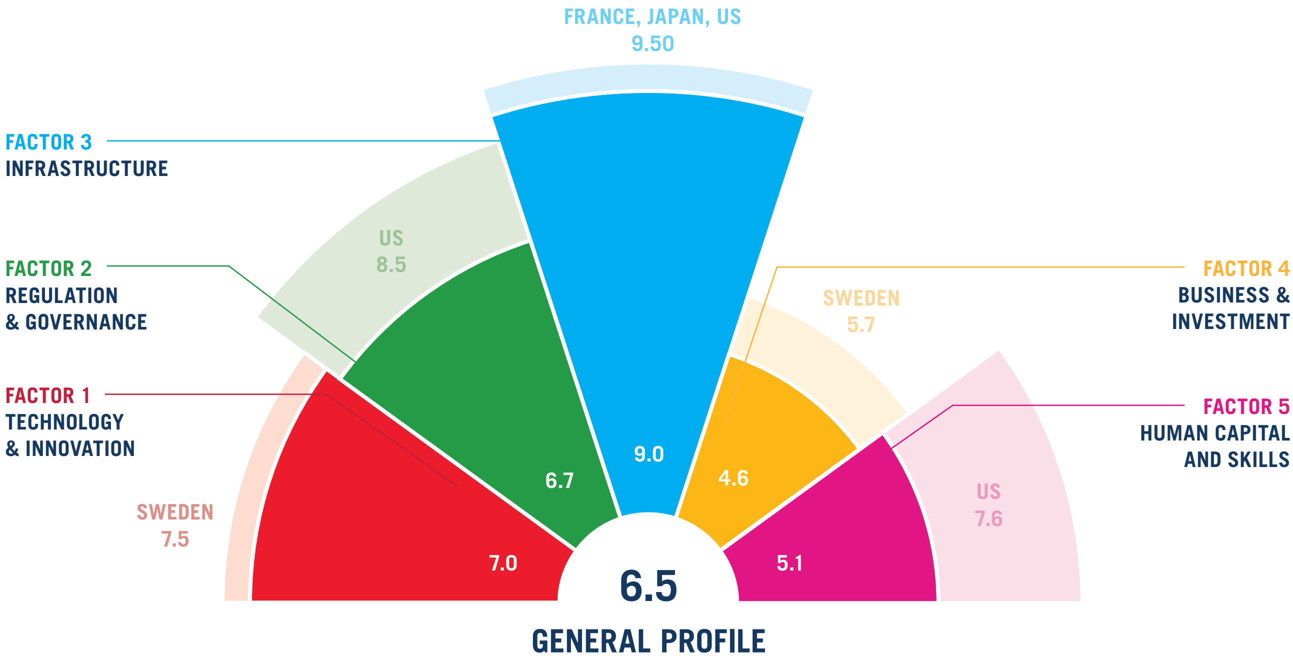
MERCHANDISE TRADE (US$)
901,618 MILLION

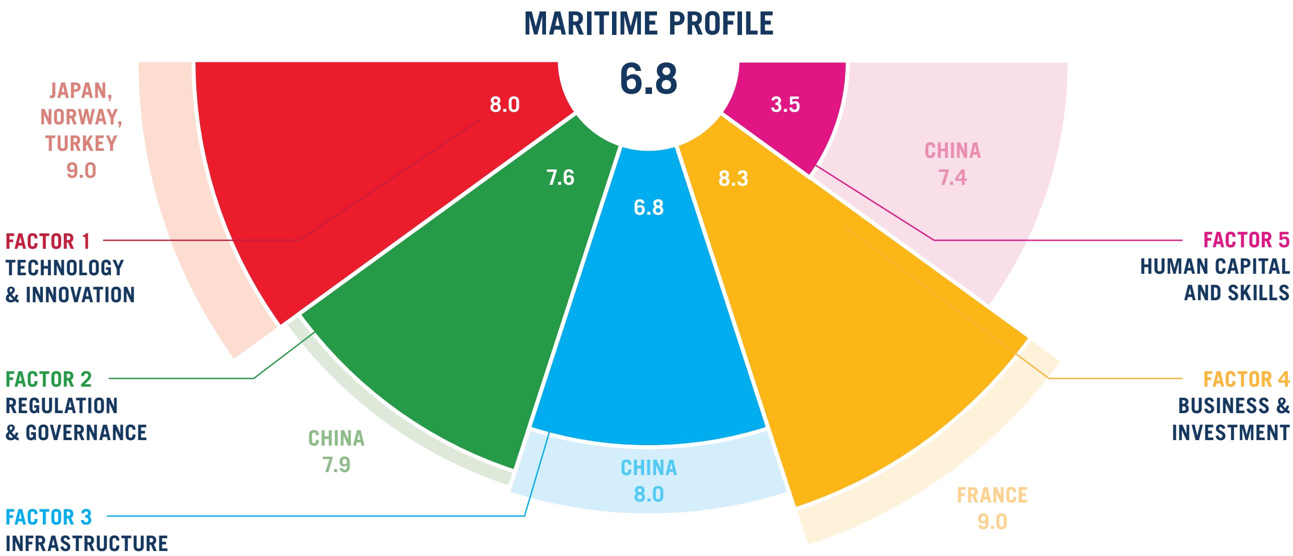
FLEET OWNERSHIP (DWT)
78,834 THOUSANDS

GDP US$ (2017)
1,411.2 BILLION

FLEET-NATIONAL FLAG (DWT)
16,987 THOUSANDS

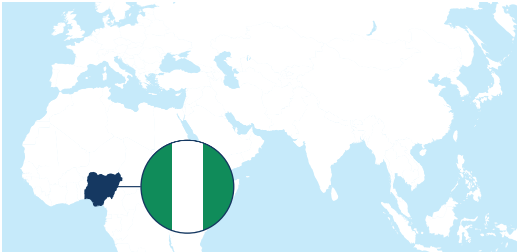
SHIP BUILDING (GT)
25,265,934





COUNTRY PROFILE

TECHNOLOGY READINESS: MARITIME



NIGERIA

KEY MARITIME INFORMATION FOR 2017

POPULATION (2017)
183.6 MILLION

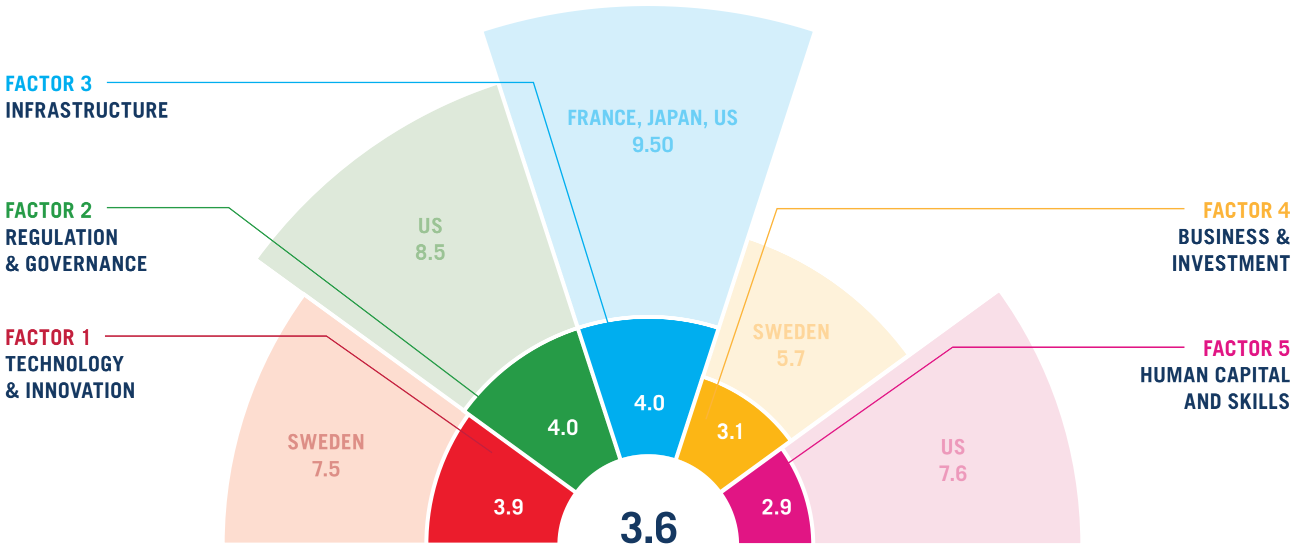
MERCHANDISE TRADE (US$)
74,000 MILLION

FLEET OWNERSHIP (DWT)
4,924 THOUSANDS

GDP US$ (2017)
406 BILLION

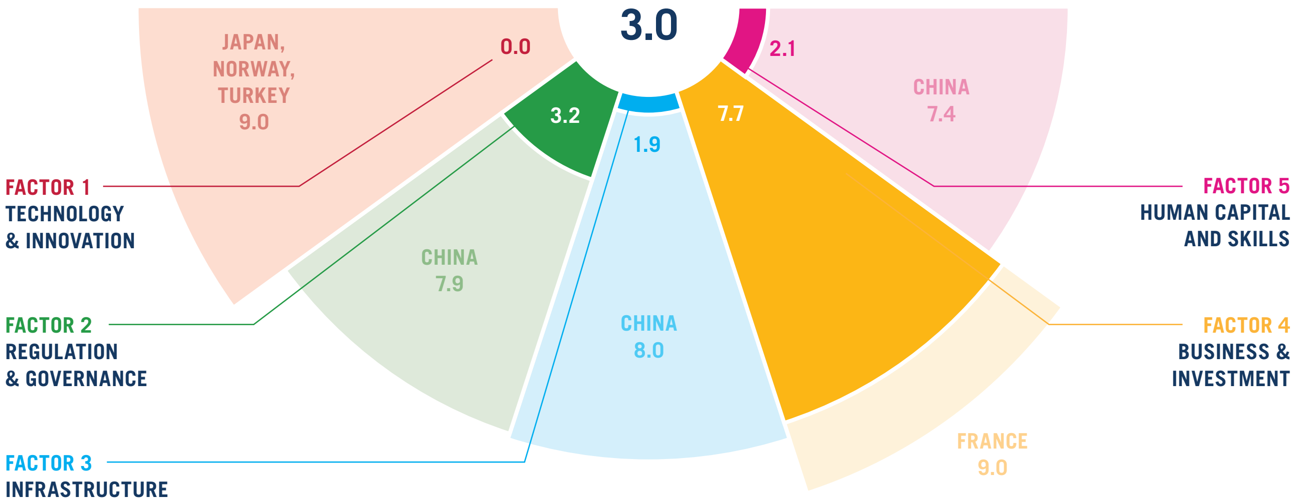
FLEET-NATIONAL FLAG (DWT)
3,623 THOUSANDS

SHIP BUILDING (GT)
..



GENERAL PROFILE

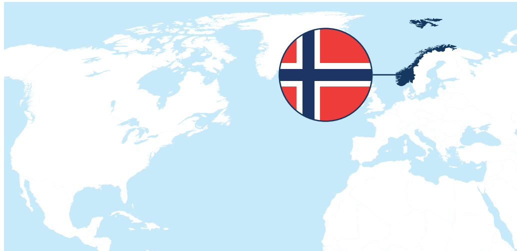
MARITIME PROFILE



COUNTRY PROFILE

TECHNOLOGY READINESS: MARITIME

NORWAY



KEY MARITIME INFORMATION FOR 2017

POPULATION (2017)
5.3 MILLION

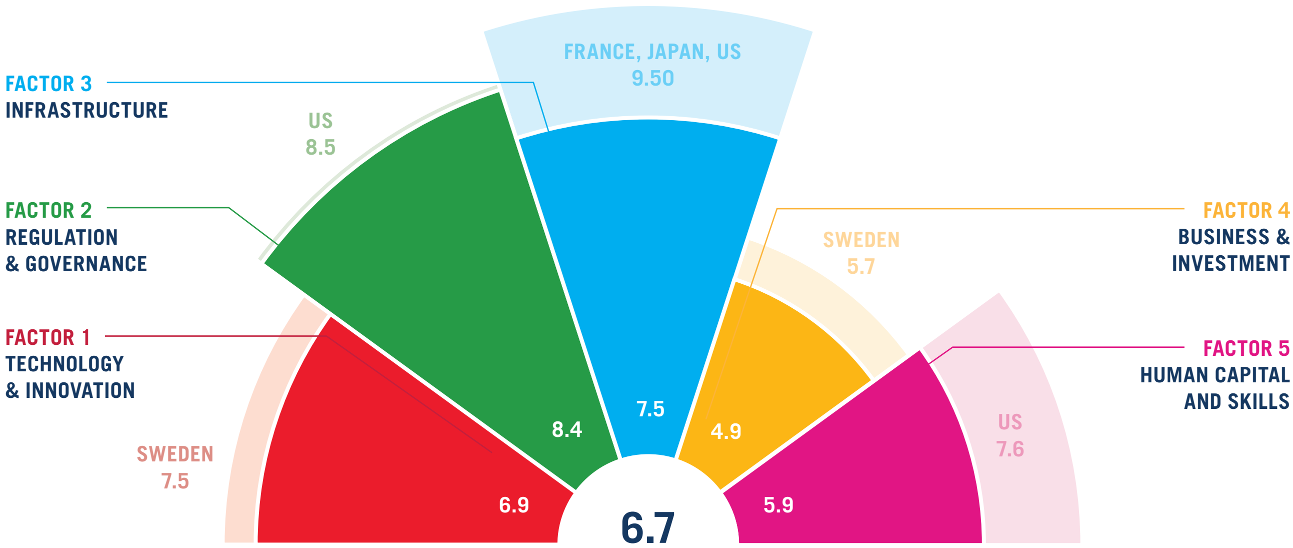
MERCHANDISE TRADE (US$)
162,152 MILLION

FLEET OWNERSHIP (DWT)
48,188 THOUSANDS

GDP US$ (2017)
370.4 BILLION

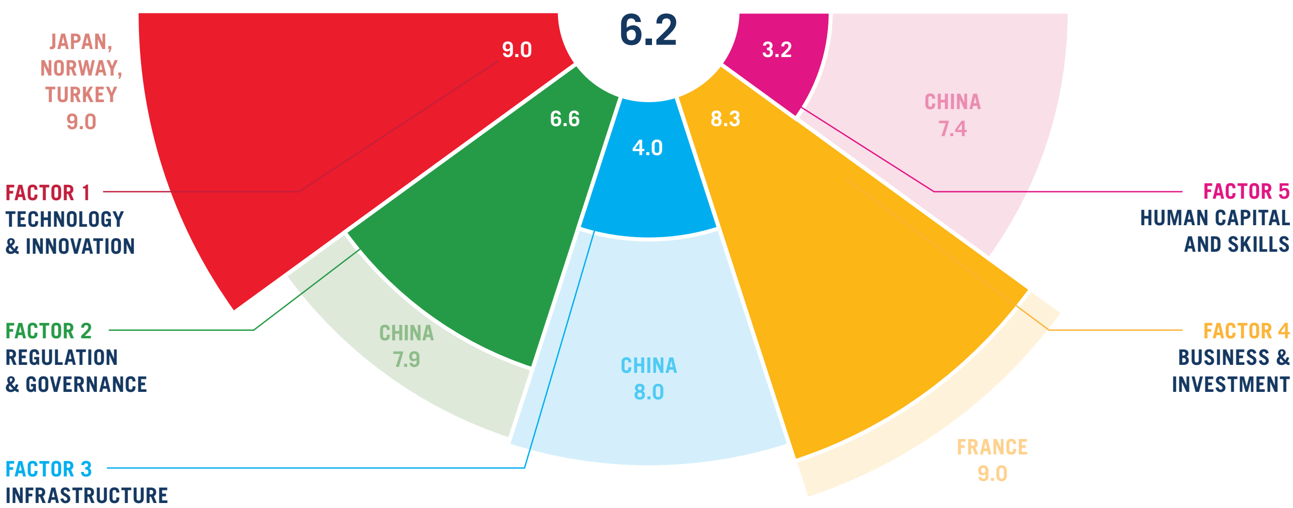
FLEET-NATIONAL FLAG (DWT)
20,073 THOUSANDS

SHIP BUILDING (GT)
161,594



GENERAL PROFILE

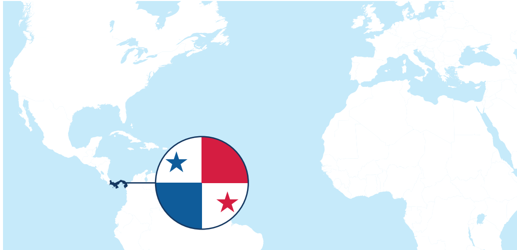
MARITIME PROFILE



COUNTRY PROFILE

TECHNOLOGY READINESS: MARITIME

PANAMA



KEY MARITIME INFORMATION FOR 2017

POPULATION (2017)
4.0 MILLION

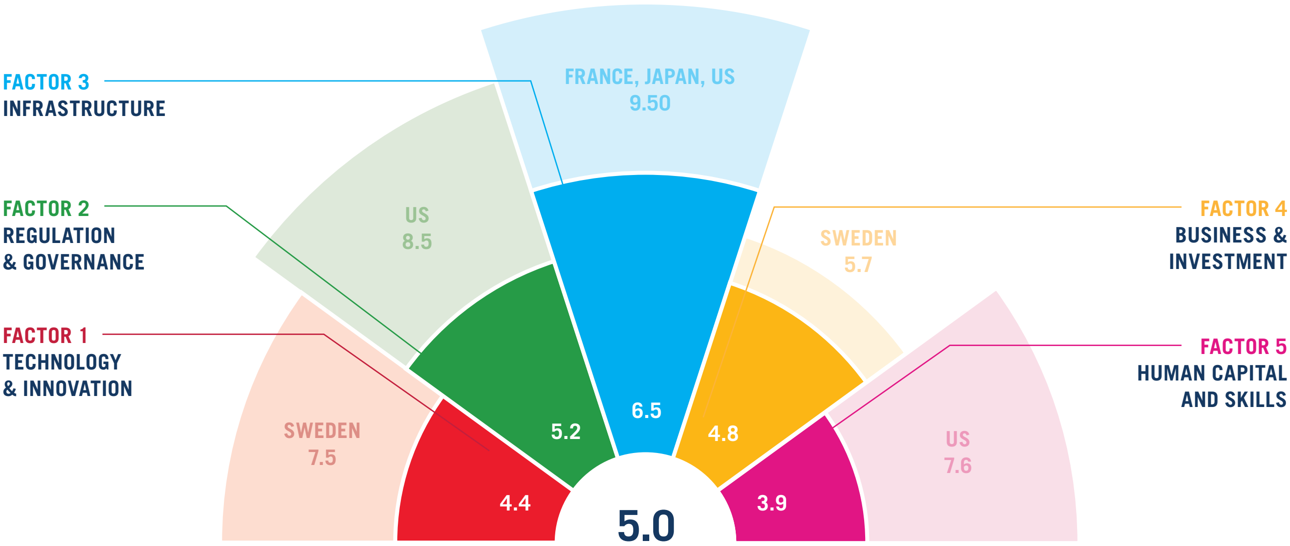
MERCHANDISE TRADE (US$)
31,764 MILLION

FLEET OWNERSHIP (DWT)
1,546 THOUSANDS

GDP US$ (2017)
55.1 BILLION

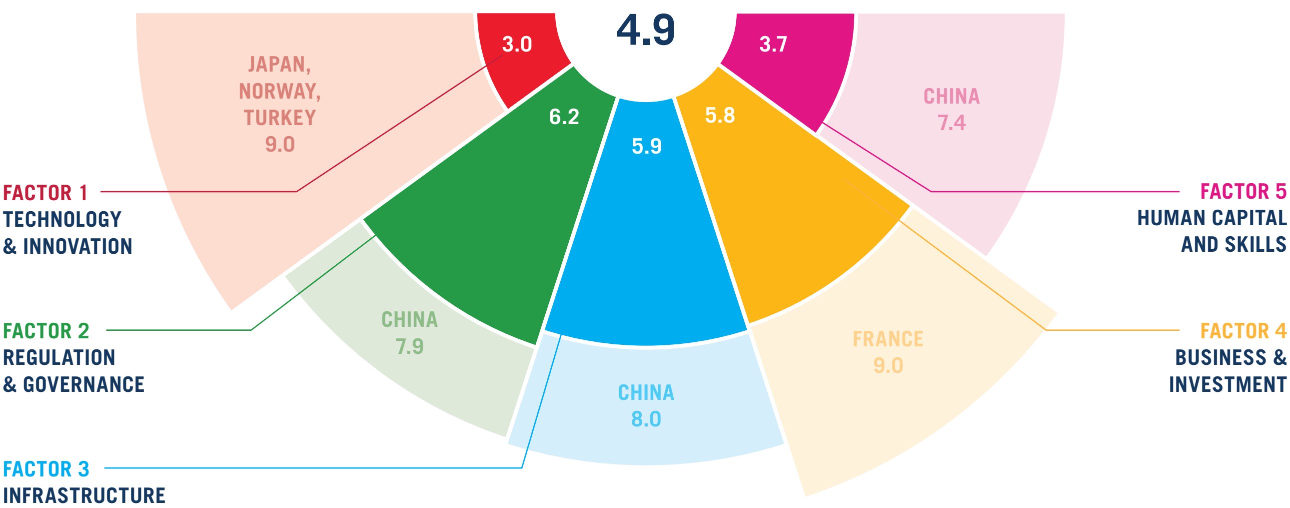
FLEET-NATIONAL FLAG (DWT)
332,878 THOUSANDS

SHIP BUILDING (GT)
..



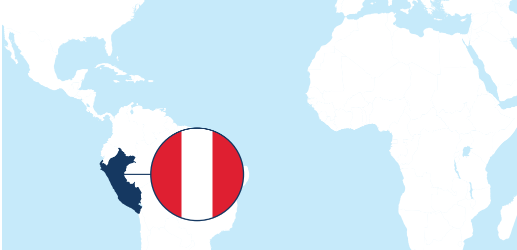
GENERAL PROFILE

MARITIME PROFILE



COUNTRY PROFILE

TECHNOLOGY READINESS: MARITIME



PERU

KEY MARITIME INFORMATION FOR 2017

POPULATION (2017)
31.5 MILLION

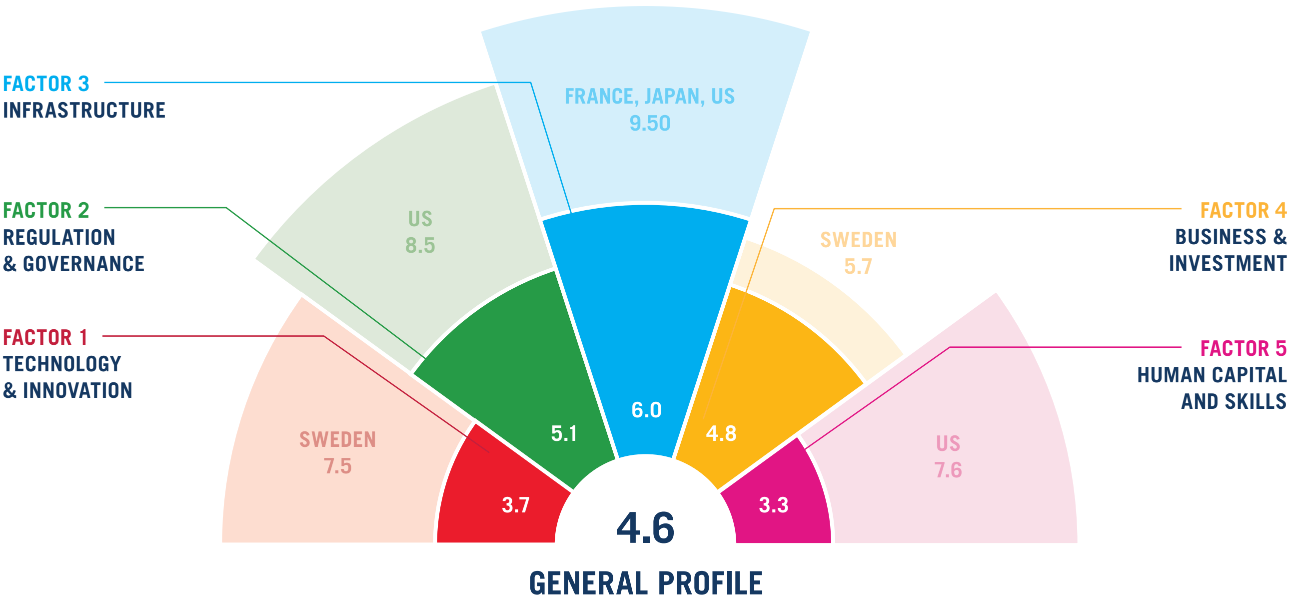
MERCHANDISE TRADE (US$)
73,285 MILLION

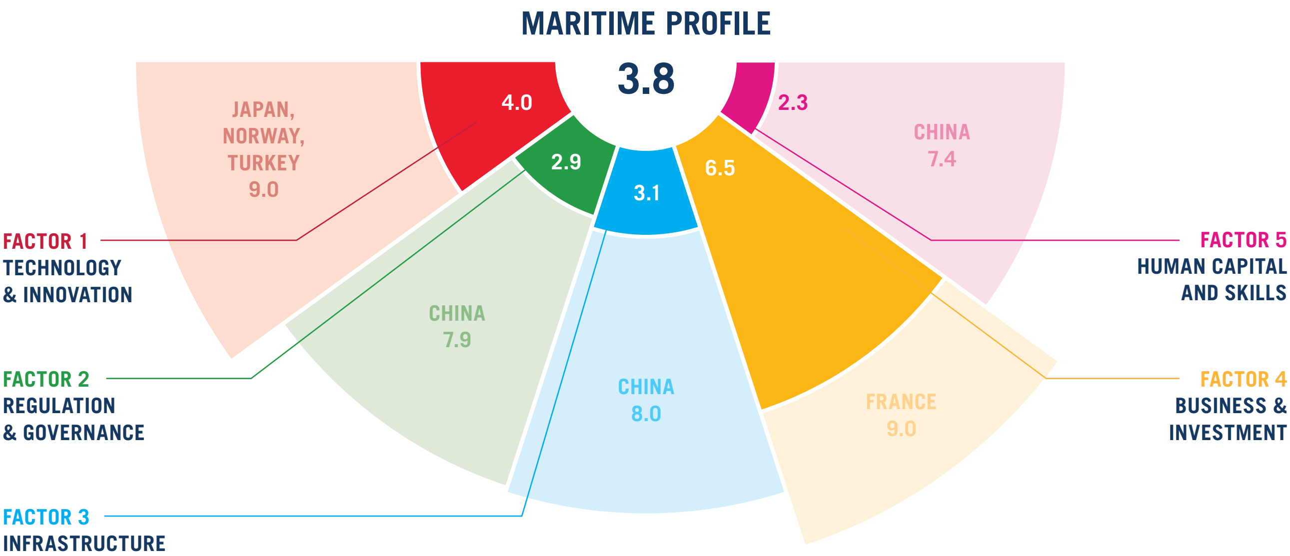
FLEET OWNERSHIP (DWT)
583 THOUSANDS

GDP US$ (2017)
195.1 BILLION

FLEET-NATIONAL FLAG (DWT)
542 THOUSANDS

SHIP BUILDING (GT)
..

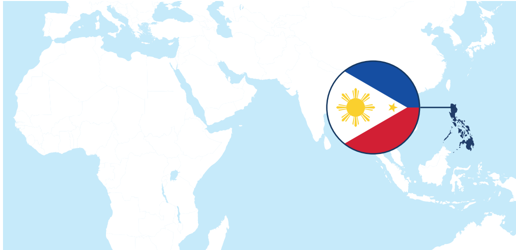




COUNTRY PROFILE

TECHNOLOGY READINESS: MARITIME

PHILIPPINES



KEY MARITIME INFORMATION FOR 2017

POPULATION (2017)
104.2 MILLION

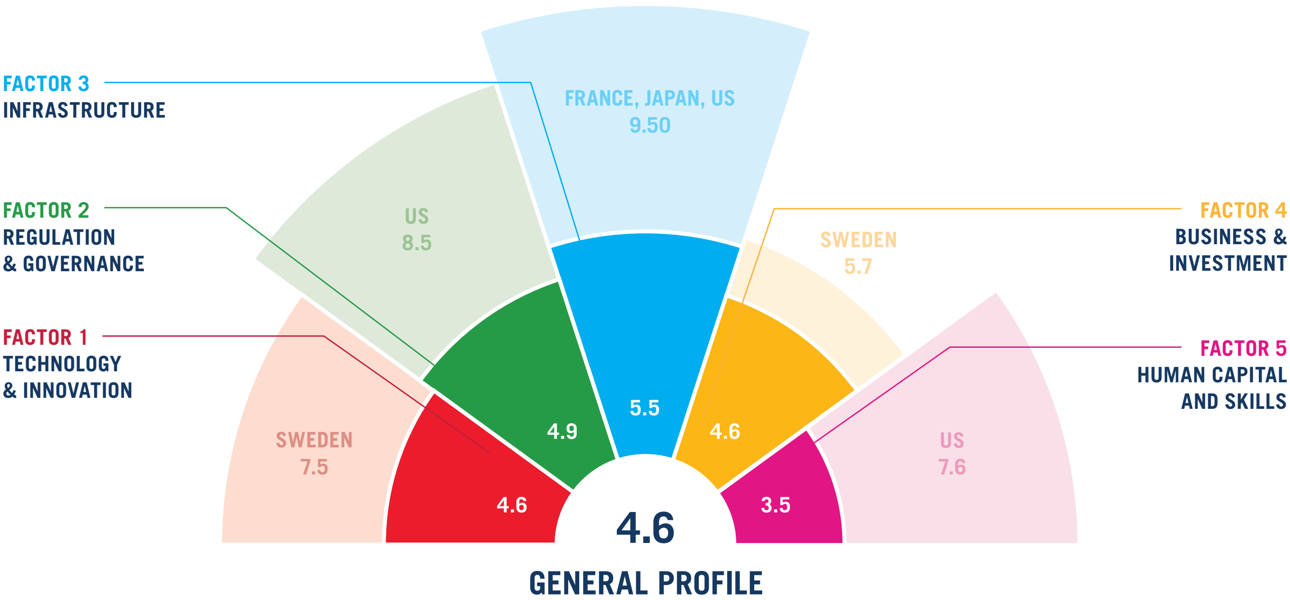
MERCHANDISE TRADE (US$)
146,841 MILLION

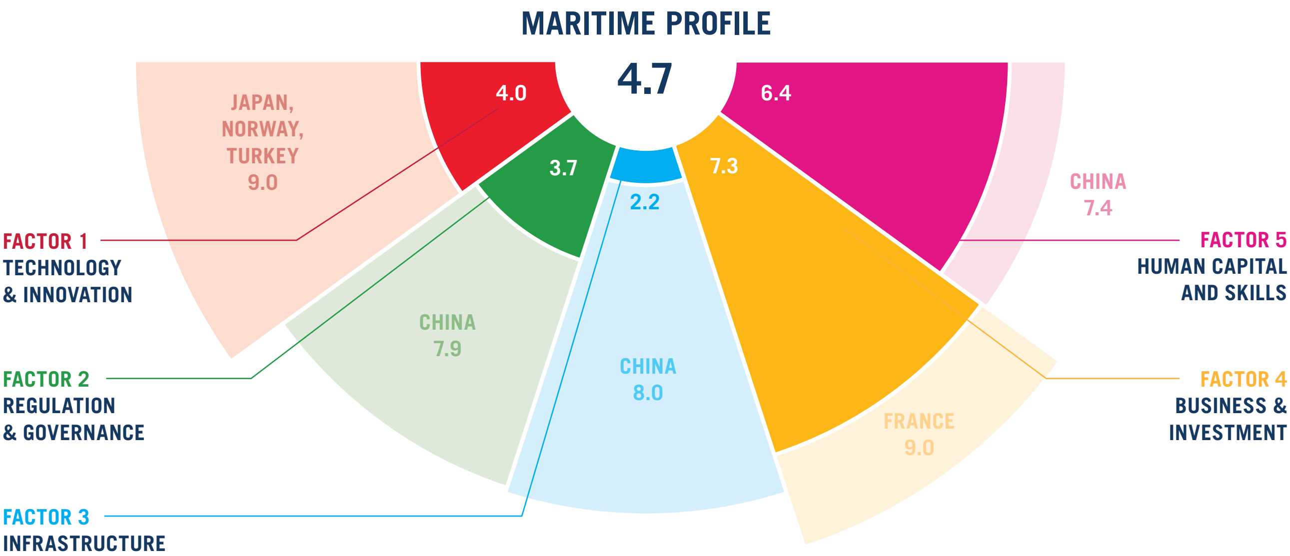
FLEET OWNERSHIP (DWT)
1,995 THOUSANDS

GDP US$ (2017)
304.7 BILLION

FLEET-NATIONAL FLAG (DWT)
6,341 THOUSANDS

SHIP BUILDING (GT)
1,168,357





COUNTRY PROFILE

TECHNOLOGY READINESS: MARITIME

SOUTH AFRICA

KEY MARITIME INFORMATION FOR 2017

POPULATION (2017)
55.9 MILLION

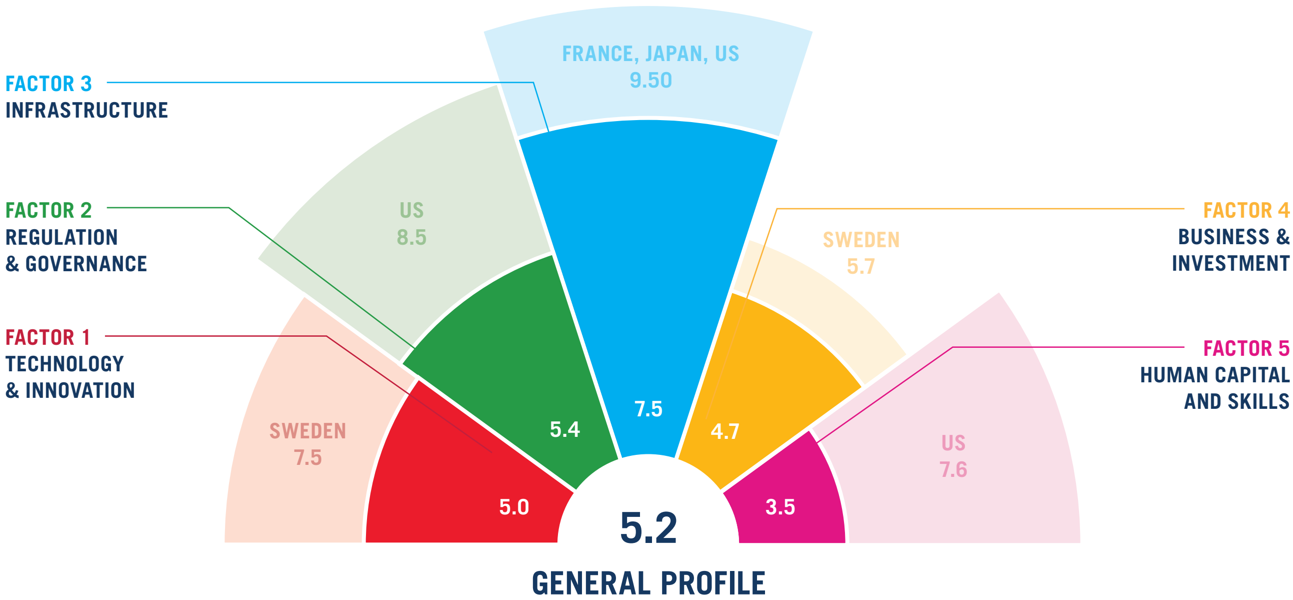
MERCHANDISE TRADE (US$)
91,592 MILLION

FLEET OWNERSHIP (DWT)
1,940 THOUSANDS

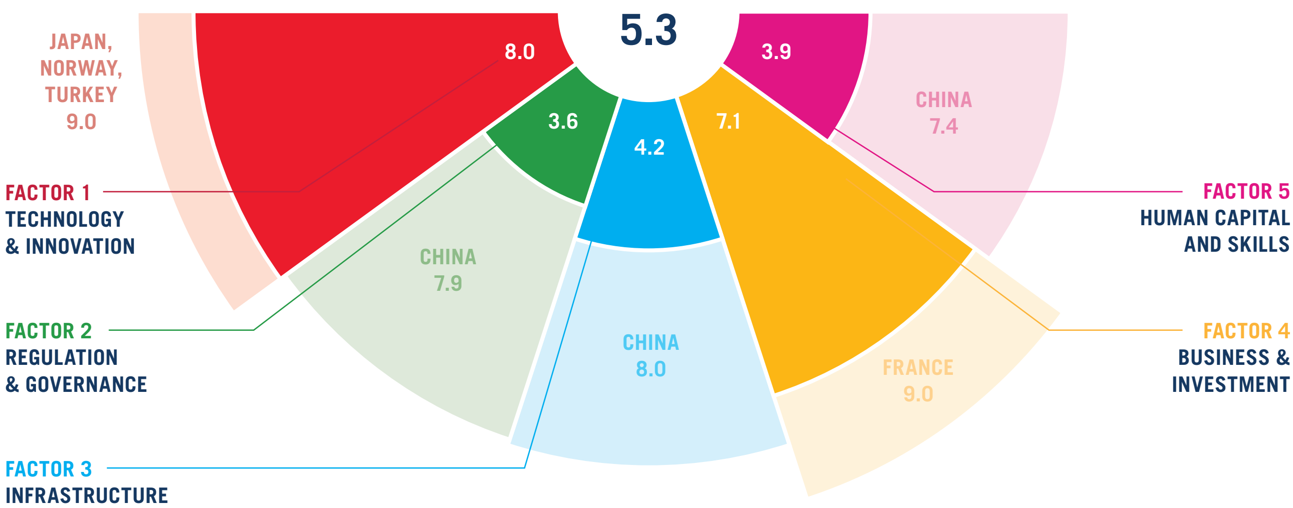
GDP US$ (2017)
294.1 BILLION

FLEET-NATIONAL FLAG (DWT)
460 THOUSANDS

SHIP BUILDING (GT)
2,999

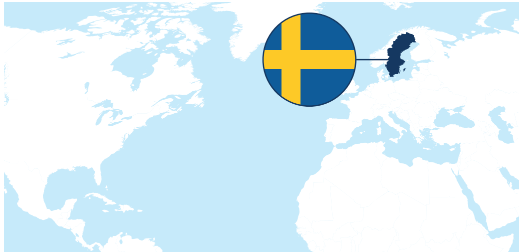


MARITIME PROFILE



COUNTRY PROFILE

TECHNOLOGY READINESS: MARITIME



SWEDEN

KEY MARITIME INFORMATION FOR 2017

POPULATION (2017)
10.0 MILLION

MERCHANDISE TRADE (US$)
280,309 MILLION

FLEET OWNERSHIP (DWT)
6,104 THOUSANDS

GDP US$ (2017)
511.4 BILLION

FLEET-NATIONAL FLAG (DWT)
1,352 THOUSANDS

SHIP BUILDING (GT)
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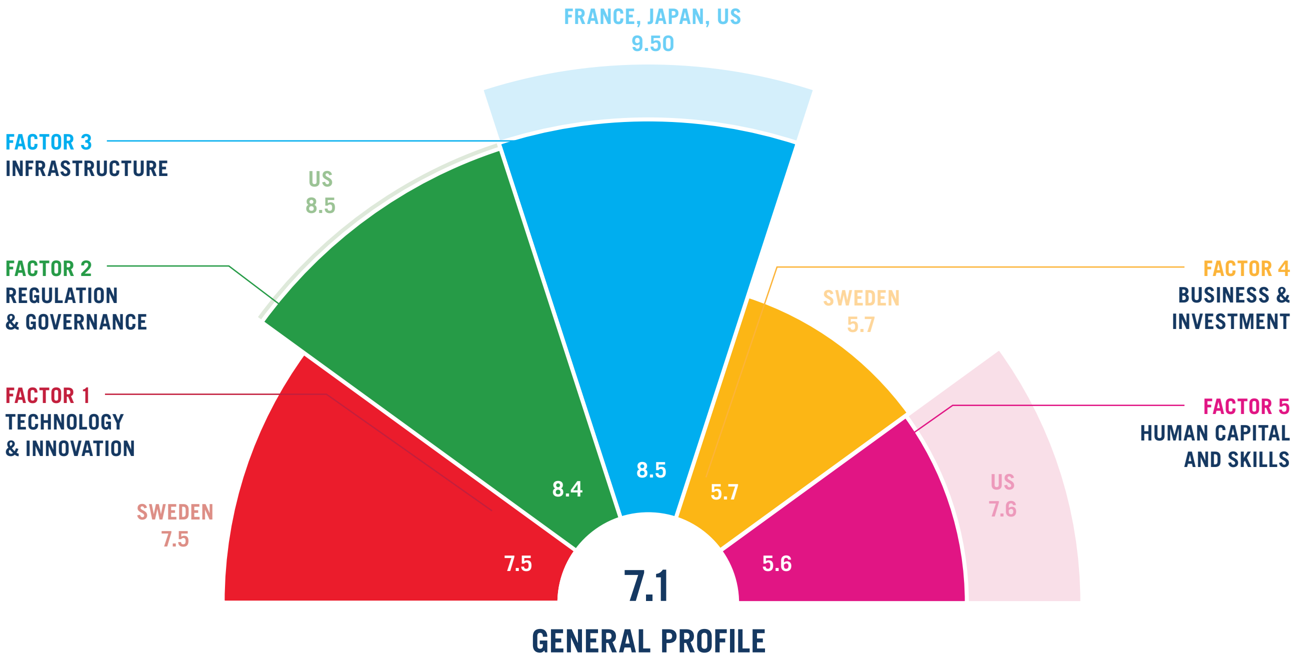
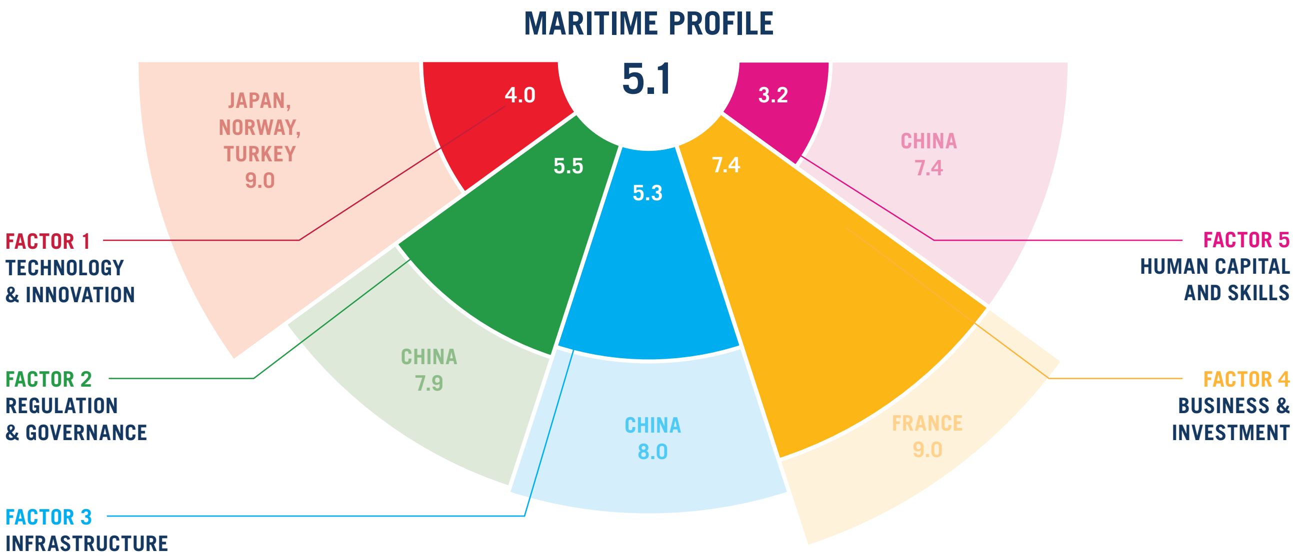




COUNTRY PROFILE

TECHNOLOGY READINESS: MARITIME

TURKEY

KEY MARITIME INFORMATION FOR 2017

POPULATION (2017)
79.8 MILLION

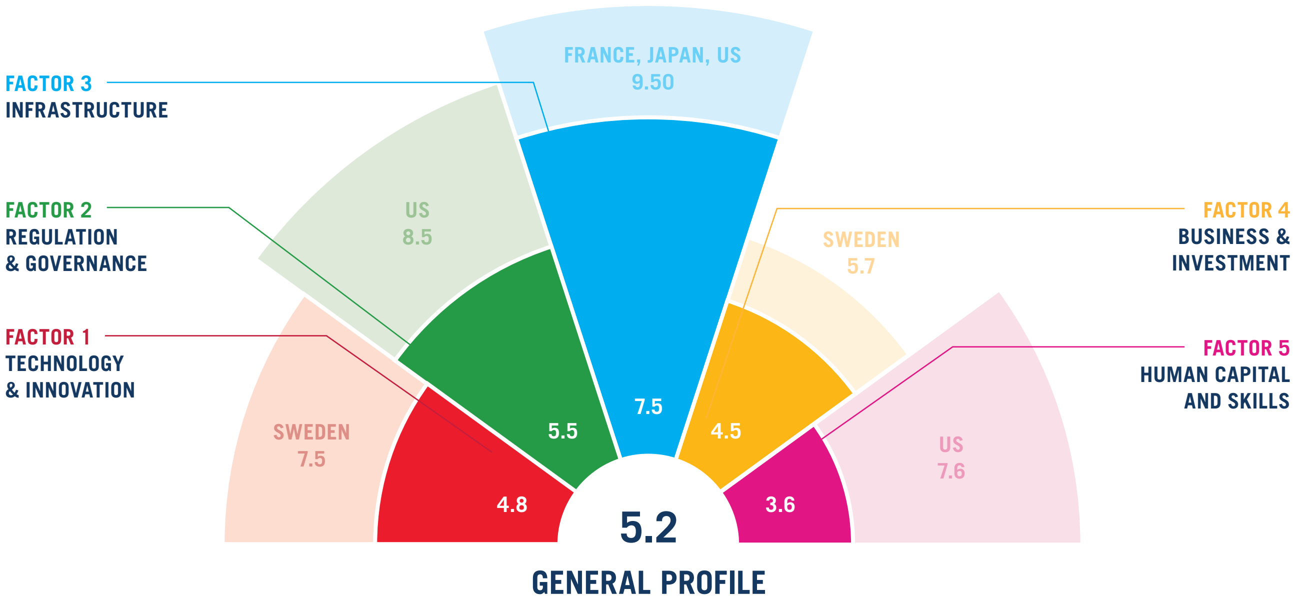
MERCHANDISE TRADE (US$)
341,148 MILLION

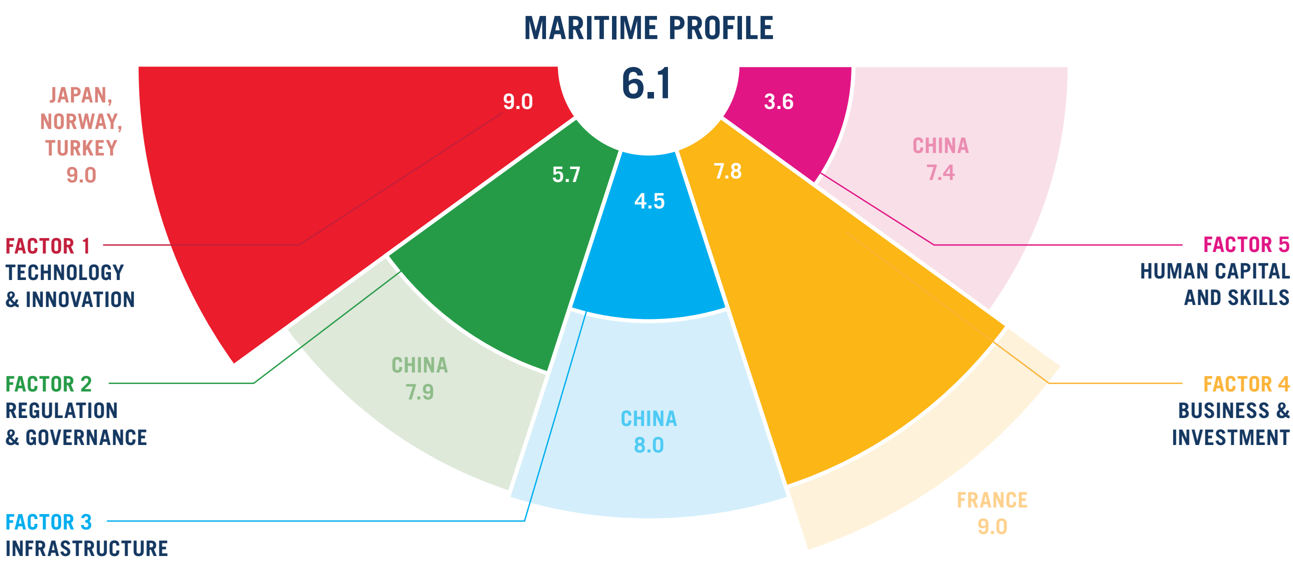
FLEET OWNERSHIP (DWT)
27,951 THOUSANDS

GDP US$ (2017)
857.4 BILLION

FLEET-NATIONAL FLAG (DWT)
8,568 THOUSANDS

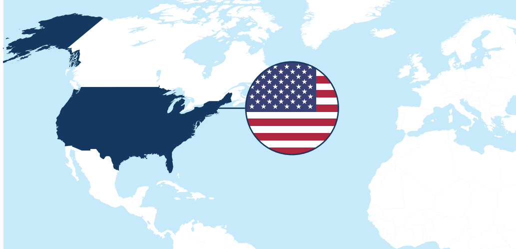
SHIP BUILDING (GT)
105,645





COUNTRY PROFILE

TECHNOLOGY READINESS: MARITIME



USA

KEY MARITIME INFORMATION FOR 2017

POPULATION (2017)
323.3 MILLION

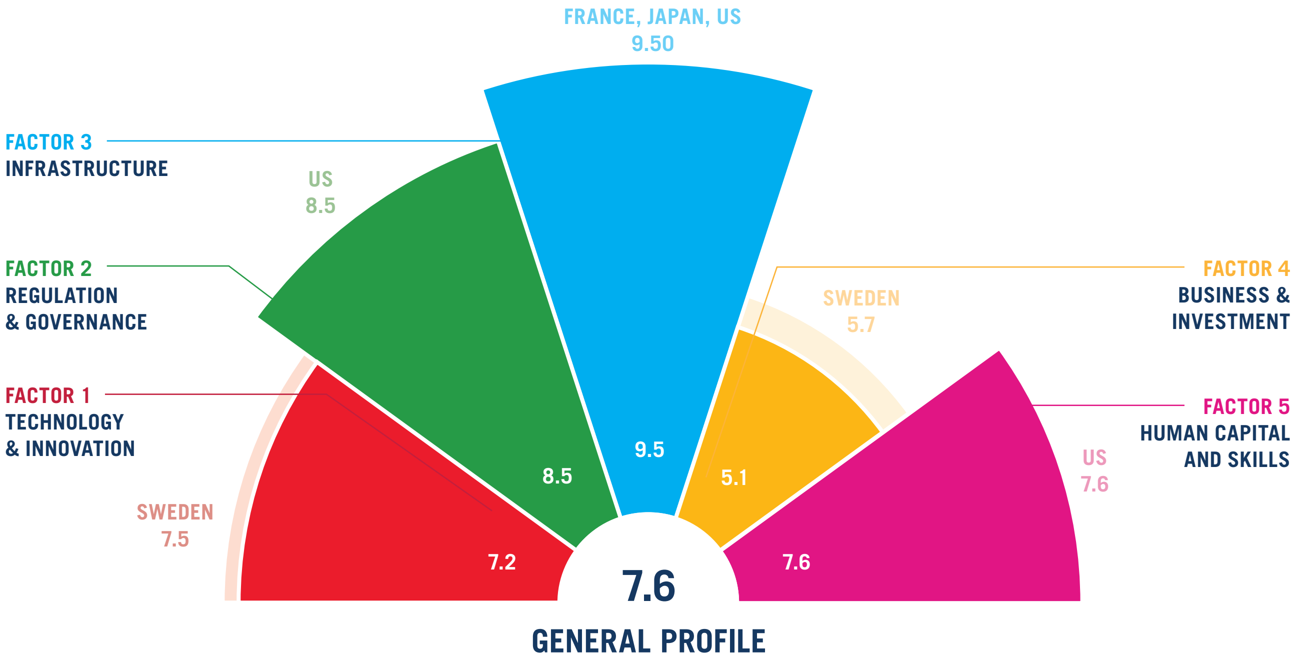
MERCHANDISE TRADE (US$)
3,701,165 MILLION

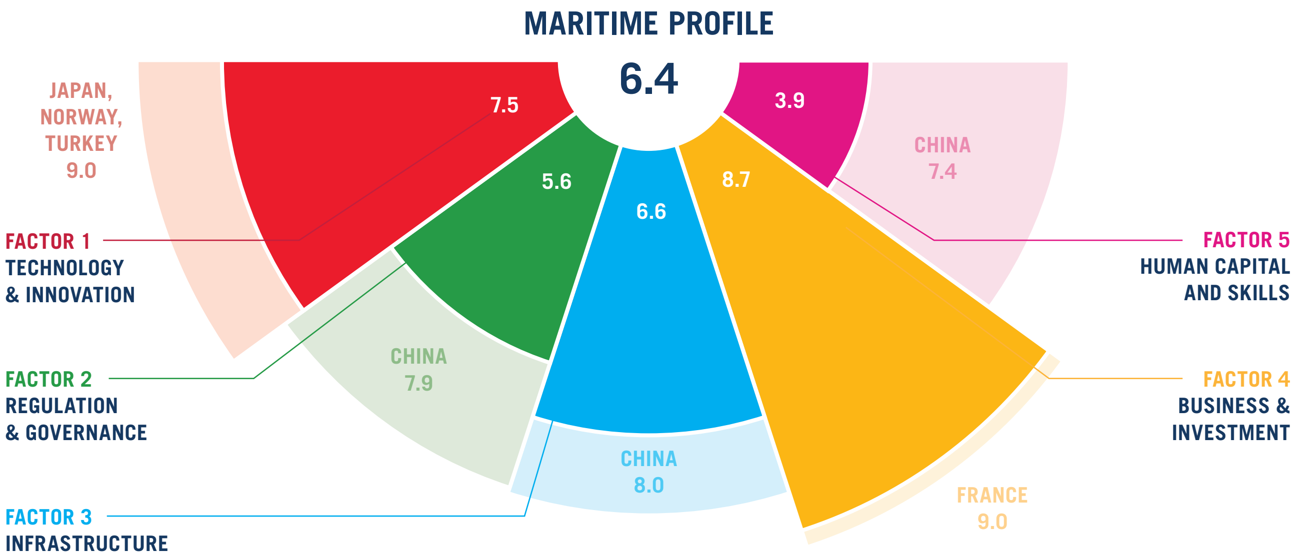
FLEET OWNERSHIP (DWT)
60,282 THOUSANDS

GDP US$ (2017)
18,569.1 BILLION

FLEET-NATIONAL FLAG (DWT)
11,435 THOUSANDS

SHIP BUILDING (GT)
344,557





WORLD MARITIME UNIVERSITY

World Maritime University
PO Box 500
S-201 24 Malmö
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www.wmu.se

The World Maritime University was established in 1983 under the auspices of the International Maritime Organization, a specialized agency of the United Nations.

INTERNATIONAL MARITIME ORGANIZATION