International Transport Forum

Adapting (to) Automation

Transport Workforce in Transition

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The International Transport Forum

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About the ITF Mobility Innovation Hub

ITF's Mobility Innovation Hub helps governments to develop innovative policies for better transport in the face of uncertainty and rapid change. It scans for transport-relevant developments at the horizon of public authority foresight, assesses their potential impacts and highlights best practices for deploying effective policies.

Case-Specific Policy Analysis Reports

Cite this work as: ITF (2023), "Adapting (to) Automation: Transport Workforce in Transition", *International Transport Forum Policy Papers*, No. 122, OECD Publishing, Paris.

Acknowledgements

Camille Combe and Changgi Lee of the International Transport Forum (ITF) wrote sections 1, 2 and 7 of this report; sections 3 to 6 were written by Marguerita Lane and Anna Milanez of the OECD's Employment, Labour and Social Affairs Directorate.

The authors thank Stijn Broecke (OECD), Jagoda Egeland (ITF) and Elisabeth Windisch (ITF) for their comments on the various drafts of the report and Hilary Gaboriau (ITF) for editorial support in the drafting process. Susanne Parandian (independent) edited the report.

The project was co-ordinated by Camille Combe of the ITF.

The work for the report was carried out in the context of the ITF Mobility Innovation Hub, funded by the Korean Ministry of Land, Infrastructure and Transport.

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Abbreviations and acronyms

AI	Artificial intelligence
AR	Augmented reality
AV	Autonomous vehicles
ADS	Automated driving system
ATO	Automatic train operation
ATP	Automatic train protection
BLS	Bureau of Labor Statistics
CCNR	Central Commission for the Navigation of the Rhine
CPUC	California Public Utilities Commission
GoA	Grades of Automation
HGV	Heavy-goods vehicle
ICT	Information and communications technology
ILO	International Labor Organization
IMO	International Maritime Organization
ISCO	International Standard Classification of Occupations
ITF	International Transport Forum
IRU	International Road Transport Union
MASS	Maritime Autonomous Surface Ships
NACE	Statistical classification of economic activities in the European Community
ODD	Operational design domain
OECD	Organisation for Economic Co-operation and Development
O*NET	Occupational Information Network
PSD	Platform screen doors
SOC	Standard Occupational Classification
UTO	Unattended train operation
VR	Virtual reality

Executive summary

What we did

This report examines the impact of the substitution of labour with capital – for short: automation – on the workforce of the urban passenger transport sector. It lays out risks and opportunities associated with automation and discusses how public authorities can steer the progress in automation in ways that support workers and help attain public policy objectives. It also assesses how automation is changing the nature of work: in terms of employment levels, job quality, required skills and the composition of the labour force in the urban transport sector. Finally, the report outlines policies that can help adapt the workforce to an automated transport labour market.

What we found

The transport sector is an important global job provider. Transport workers represented around 7% of the world's total employment in 2017, equalling almost 170 million direct jobs. Less than 20% of transport workers are women. And the transport workforce is ageing rapidly. In 2019, 52% of Europe's transport workers were older than 45 years. These demographic characteristics create a challenge for the sector.

Transport relies on a wide range of professions to function efficiently. These different transport-related occupations also have diverging potential of being automated.

From a skills perspective, occupations at high risk of automation include vehicle occupations, maintenance occupations and operations occupations. Urban passenger transport workers with low and medium levels of education are more exposed to automation and may struggle to adapt.

From a gender perspective, men's skills and abilities are more exposed to automation than those of women. However, the current gender gap in digital skills and women's underrepresentation in jobs related to information and communications technology (ICT) and artificial intelligence (AI) suggests that men might adapt to such a challenge more easily than women.

Older workers may confront preconceptions regarding their ability and willingness to master new technologies. On the other hand, tenure and seniority may afford greater protection than younger workers enjoy.

Automation redefines the skillset in which humans have a comparative advantage over machines. Some highly automatable skills are currently oversupplied, for instance, physical abilities, quantitative abilities or installation and maintenance skills. Employees with these skills and occupations will face increased competition from other workers with similar skills and from automation. They will be most in need of opportunities for adult learning to be able to pursue their occupations and adapt to new job requirements.

In some areas of the urban passenger transport sector, automated solutions do not yet work fully. These include roles that require cognitive skills for service, management and planning. Some skills are not so easy to automate, for instance, financial management, persuasion and negotiation. Roles with such skills already face worker shortages, which are likely to increase in the future.

The technological changes, such as those introduced by artificial intelligence (AI) technologies, could bring a number of labour benefits to the urban passenger transport sector.

Automation can generate new employment opportunities and improve working conditions. New jobs could include self-driving fleet operation technicians, safety drivers, and specialised AI and automated vehicles software engineers. Automation may also alleviate some labour shortages, particularly for the dearth of drivers that some countries face.

Automation could also improve occupational safety and health. Automating dangerous and repetitive tasks can reduce the risk of injury and strain, and the different ways workers interact with machines can reduce their exposure to hazards.

That said, automation technologies can also introduce new risks to the nature and quality of work. Artificial Intelligence (AI) technologies can increase work intensity and stress levels when used to monitor workers or make decisions.

A number of uncertainties with regard to other benefits of automation technologies for the urban passenger transport sector remain. For businesses, increasing productivity is generally a major motive to automate. Whether workers would also benefit from these in the form of higher wages is uncertain, however.

Automation and digitalisation could improve work-life balance within the transport sector by providing opportunities for more flexible working hours and remote work. This is likely to attract more women to the sector and help to narrow the sector's gender gap. Flexible working can improve working conditions for groups that are underrepresented, such as women, but only as long as flexibility truly serves the needs of the workers. If flexibility only serves the needs of the business and its customers, it risks undermining job quality.

What we recommend

Incentivise companies and individuals to invest in adult learning

Many companies and individuals lack the resources to invest in adapted adult learning to address new challenges in the transport sector. Public authorities can help bridge the funding gap by incentivising employers to devote funds to skills development. This can be achieved through various financial incentives schemes, including help to secure access to financing, tax incentives and co-funding schemes between public authorities, individuals and employers. Financial incentives should be targeted towards employers and individuals most in need.

Transform education systems so they transmit the skills needed for the era of automation

Education plays a pivotal role in anticipating the future skills supply and mitigating potential negative impacts caused by technological change. The unpredictable nature of automation calls for a lifelong and more flexible education system. Inadequate education could prevent the transport workforce from acquiring the skills the sector will demand in the future. Schools and universities that fail to transmit these skills could impede the ability of young people to find jobs. The education system should, therefore, transform and align with the demands of the era of automation.

Take an anticipatory approach to managing the impacts of automation

Governments should carefully analyse the potential impacts of emerging technologies on the transport workforce before deciding how to manage automation. For a smooth adoption, they should involve stakeholders in the urban passenger transport space in developing a well-tailored framework for governing automation and guiding policy both at the national and international levels.

Steer technological change towards desired societal benefits through targeted regulation

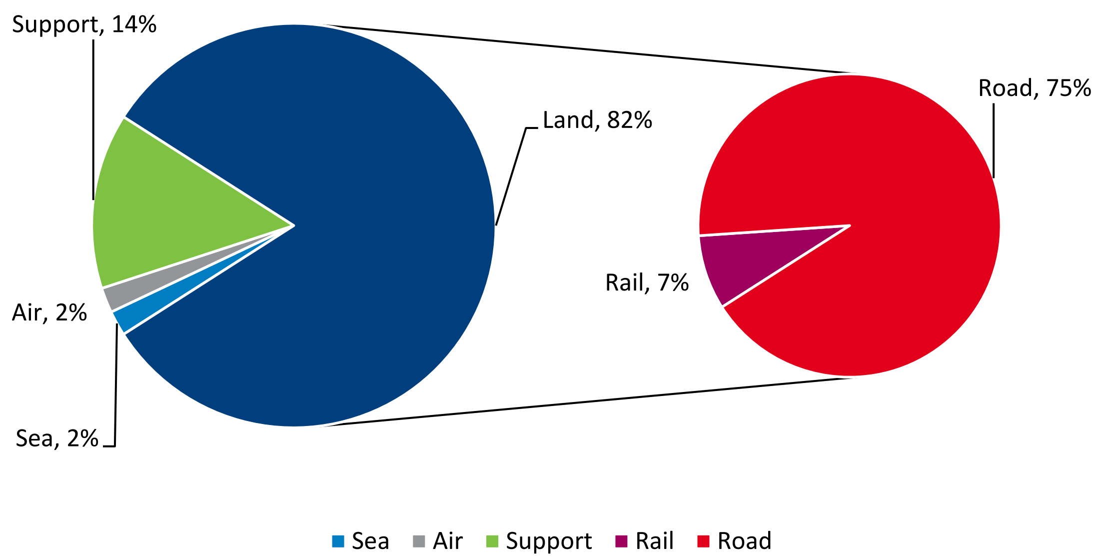
Targeted regulation should ensure automation in the urban passenger transport sector occurs in line with the needs of users and society as a whole. Market-driven technological progress may not itself lead to optimal outcomes, and public authorities, an inclusive social dialogue, collective bargaining and research input from labour organisations should play a vital role and will prove beneficial in shaping a desirable future of work in this sector.

Trends in transport jobs

The transport sector is the world's third-largest job provider. The World Maritime University (2019) estimates that transport workers represented approximately 7% of the world's total employment in 2017. This percentage corresponds to 168 million direct jobs, excluding agriculture-related activities. Furthermore, transport supports millions of jobs in other industries. For example, in the European Union, almost 29 out of every 1 000 people work in the transport sector (i.e. approximately 5% of total employment), with significant variations between regions.

A modal breakdown of the global workforce shows that the distribution across transport modes is not even (World Maritime University, 2019). Land transport accounts for more than two-thirds of total employment in the transport sector (82%). Within land transport, road transport represents 92% of total employment, while the remaining 8% corresponds to rail transport (Figure 1).

Figure 1. Global employment distribution across the transport sector by mode



Source: World Maritime University (2019).

To get a more accurate picture of transport sector employment, it is important to consider informal jobs. The International Transport Workers' Federation (2019) notes that most transport workers are informal. In regions like Asia and Africa, an essential part of passenger transport services is informal, yet they provide jobs for thousands of workers in various occupations (e.g. drivers, mechanics). Precise statistics on these different forms of contracts are complex to gather due to the less informal dimension of employment. In the Global South, where informal transport plays a major role in daily mobility, official figures may not provide a true picture of employment in the sector (UITP, 2021).

Informal jobs are also associated – but are not synonymous – with precariousness. Precariousness comprises various dimensions (e.g. poor wage, insecurity, unprotected employment, no pension). However, formal activities (e.g. covered by formal arrangements) can also be precarious. Recent technological developments associated with the gig economy[1] in the transport sector (e.g. deliveries, ride-hailing services) contributed to the development of precarious jobs in the transport sector in developed countries (International Transport Workers' Federation, 2019). These jobs offer flexibility and skills for workers. Still, they often come with few employment rights and face job insecurity with little or no access to social protection (e.g. ineligibility to unemployment insurance).

Transport's demographic challenges

Population structures and employment legacies around the globe significantly affect the workforce and impose additional challenges on industries. The transport sector faces several issues related to its workforce, including gender imbalance and an ageing workforce.

A strong gender imbalance characterises the transport sector. Women constitute just 20% of the transport sector's total employment. They face substantial obstacles (e.g. discrimination, abuse, harassment) when it comes to gaining access to training and licensing, which hinders their capacity to gain experience (ETF, 2017). This situation exacerbates the gender imbalance in transport sector employment (International Transport Workers' Federation, 2019). Women workers in the informal transport economy face even more uncertainty with poor working conditions (e.g. insecurity, low pay). The gender composition of the urban transport sector is discussed in greater detail below (see section "The impact of automation on inclusiveness").

The transport labour market is characterised by a high share of older drivers (aged 55 or above). This situation and the difficulty of hiring young drivers increase the risk of driver shortages. In 2021 and 2022, several countries suffered from driver shortages due to internal factors, including minimal legal age for a heavy-goods vehicle licence, and external factors, such as the consequences of the pandemic or reskilling. The IRU (2022) notes that the COVID-19 pandemic had a more significant impact on longer-distance services (e.g. heavy-goods vehicles, long-haul buses) due to several factors (e.g. ageing workforce, attractiveness of profession) and will take longer to recover. UTP (2022) notes that the impact of COVID-19 restrictions contributed to difficulties in recruitment in the transport sector due to its lack of attractiveness. In Europe, 6.7% of bus and coach driver positions, and 9.7% of heavy-goods driver positions were unfilled in 2021.

Attracting young workers is a challenge for the sector. In Europe, workers under the age of 35 tend to be underrepresented (29% of total workers) compared to workers over 50 years of age (37%). In France, OPTL (2020) notes that the share of transport workers over 45 years of age increased from 43% in 2009 to 52% in 2019. The section on labour force composition also discusses potential impacts of automation on workers of different age groups (see section "Which skills in the urban transport sector are at risk of automation").

An uneven distribution among skills

The transport sector relies on a variety of occupations to function efficiently. Not all occupations have the same risk of being automated. Some occupations require skills that are harder to automate. The transport sector is characterised by an uneven distribution of skills needs. Depending on the sector, occupations will require different skills (e.g. dockers, drivers, and traffic engineers). This uneven distribution of skills suggests that automation could affect certain sectors more than others. Box 1 outlines various skill requirements and levels needed for different occupations.

Box 1. Occupations and their skill levels

A skill level is "a function of the complexity and range of tasks and duties to be performed in an occupation" (ILO, 2012). It can be measured by considering several factors, namely, the nature of the work performed (e.g. tasks, duties), the level of education required and the amount of experience needed to complete the tasks and duties related to the occupation (ILO, 2012). The International Labor Organization (ILO) created the International Standard Classification of Occupations (ISCO-08), which proposes a classification of the different occupational skill levels. The World Maritime University (2019) proposed a three-grade scale (low, medium and high) based on ISCO-08 skills levels to create skills categories (see Table 1).

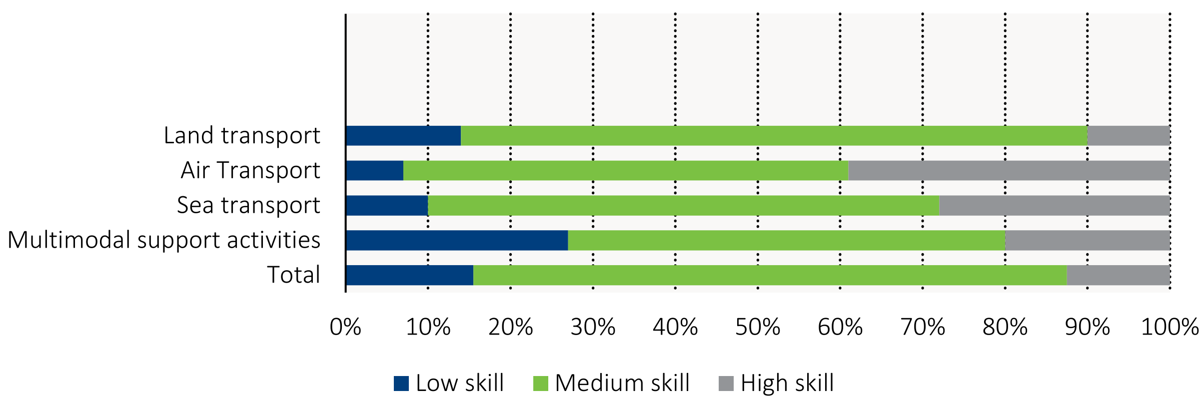
Table 1. Skill levels, tasks performed and associated job type

ILO's skill classification	1	2	3	4
ILO's description of the occupation	Simple and routine physical or manual tasks	Tasks such as operating machinery and electronic equipment; driving vehicles; maintenance and repair of electric and mechanical equipment; manipulation, ordering and storage of information	Complex technical and practical tasks that require an extensive body of factual, technical and procedural knowledge in a specialised field.	Complex tasks involving problem-solving, decision making and creativity based on an extensive body of theoretical and factual knowledge in a specialised field.
World Maritime University's skill classification	Low skill	Medium skill	High skill	
World Maritime University's task-level description	Physical task	Routine task	Cognitive/Abstract task	
Type of jobs	Dock worker Freight handler Warehouse worker	Drivers Vehicle operator (e.g. crane, forklift)	Airline pilot Ship engineer	Air traffic controller Traffic engineer

Source: Based on ILO (2012) and World Maritime University (2019).

An analysis of job distributions shows that the transport sector relies heavily on middle-skilled jobs, or ILO's skill level 2 group. This segment accounts for 72% of the total transport workforce. A modal breakdown shows land transport's reliance on middle-skilled jobs is even greater (76%). This category mainly includes occupations that require driving tasks (e.g. HGV or bus driver, machine operator). Transport service provision falls into this category. Low-skilled groups (e.g. handler, porter) and high-skilled groups (e.g. engineers, managers) respectively account for 15% and 12% of the total workforce (see Figure 2). Available data for Europe show that the proportion of high-skilled workers in the labour market is greater (34.9%) than in the transport market. Figures for low-skilled occupations are similar (15.8%) (ILO, 2010).

Figure 2. Distribution of workers by skills and modes



Source: Based on data from the World Maritime University (2019).

Skills required in the urban transport sector and how skill needs are changing are explored below (see section "How automation changes skill needs").

How technology transforms transport

Ongoing technological transformations within the transport sector (e.g. digitalisation, electrification, automation) are associated with opportunities and challenges. From a labour perspective, introducing and benefitting from new technologies will require workforce development to avoid any skill gap and associated shortages. Addressing these issues may affect the workforce and skill distribution.

Understanding and assessing the potential impacts of automation on labour may benefit from other recent technological transformations. For example, the "datafication" (Cukier and Mayer-Schoenberger, 2013) of transport is associated with an increasing need for data specialists to analyse and manage transport data. Chinn et al. (2020) indicate that Europe and the United Kingdom would need an additional 1.7 million jobs with technical skills for the public sector to close the data literacy and management skills gap by 2023. This figure represents approximately 5.3% of the 32 million jobs in the public sector. Transport Systems Catapult estimated that the UK transport industry would need 3 000 data-related jobs to enable data-sharing promises (Transport Systems Catapult, 2015).

Transport automation

Automation is a continuation of a broader process of technological development. Transport has been at the forefront of technological progress from a historical perspective. Watt's steam engine and the Industrial Revolution of the 18th century allowed societies to overcome the limitations of muscle power (Brynjolfsson and McAfee, 2016). It enabled the generation of massive mechanical power and further led to the development of railways, trains, manufacturing plants, cars and our modern societies. In more recent decades, progress in computerisation and digitalisation, or the "Second Machine Age" (Brynjolfsson and McAfee, 2016), allowed humans to "overcome the limitations of mental power".

Transport automation: Technologies, skills and people

Automation within the transport sector results from a conjunction of different factors. On the one hand, the recent progress in computer technology (e.g. artificial intelligence, machine learning) has redefined the tasks machines can perform. Automation is expected to bring many benefits, such as reducing the cost of vehicle operation, improved reliability, enhanced safety and reduced use of space in cities (Becker et al., 2020; Bösch et al., 2018).

While much of the focus is on self-driving vehicles, automation may also transform other activities and products within the transport industry (ITF, 2015; Smith, 2014), such as dispatchers, travel agents and ticket clerks.

Automation refers to a range of technologies that can be implemented at different levels (e.g. service management, back office, vehicle operation and manufacturing) and at different time horizons due to their complexity. This report will consider the following:

- The automation-related technologies used for the <u>management</u> of transport services (e.g. back-office jobs, information systems, infrastructure management, etc.). This includes artificial intelligence (AI) applications to facilitate tasks such as trip planning, pathfinding, fraud detection, risk assessment, marketing, matching drivers and riders, etc.
- The automation-related technologies used for the <u>operation</u> of the transport services, such as automated vehicles, or technologies responsible for some or all the driving tasks (e.g. sense, perceive, localise, plan, control). This includes artificial intelligence and machine learning-related technologies. It also includes predictive maintenance of vehicles.

This report will not consider the technologies that facilitate the manufacturing process of vehicles (e.g. robotics) or the building process for the enabling infrastructure.

Tasks and skills

Automation's impact on workers will vary depending on the type of job performed. Within urban passenger transport, the extent to which a job is automatable will depend on the capacity of automated systems to perform the occupation's related tasks better than humans. Performance is multi-dimensional and can be expressed as:

- efficiency (e.g. functioning without disruption and at lower costs) (Ford, 2015)
- persistence (e.g. working over a long period) (Brynjolfsson, Liu and Westerman, 2022a)
- reliability (e.g. accuracy of the information provided, on-schedule service)
- safety (e.g. working conditions, operation).

The frontier between what is “automatable" and what is not is continually evolving (Ford, 2015). While lower-skilled jobs will continue to be affected, a growing part of highly-skilled jobs may be increasingly concerned. Rapid progress in artificial intelligence and predictive algorithms may enable automating tasks that, up until now, have required a high level of education and skills. In 2023, generative AI tools (e.g. ChatGPT, DallE2, Midjourney, etc.) showed significant progress in performing tasks that require cognitive abilities, foreshadowing a potential impact on white-collar jobs.

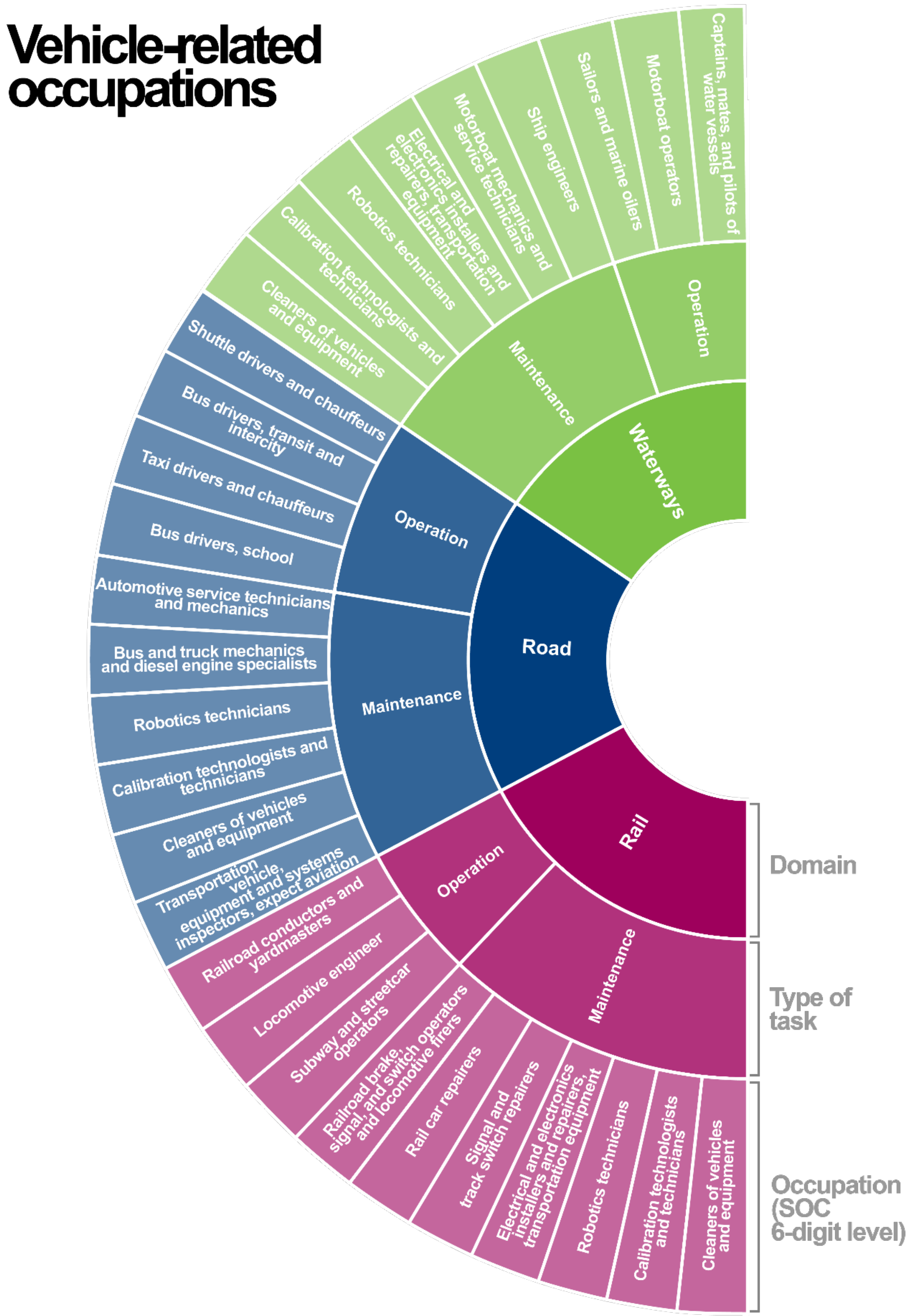
Assessing the urban passenger transport workforce

Urban passenger transport workforce jobs can be categorised into those linked with vehicle operation (drivers, repairers, cleaners, dispatchers, etc.), infrastructure (planners, maintenance workers, signal repairers, etc.) and the transport service itself (reservation and ticket clerks, travel agents, passenger attendants, etc.). Jobs can be further distinguished by role (e.g. management, maintenance, planning, operation). The job categories are based on the Occupational Information Network database's (O*NET) typology of occupations. Figure 3 provides a detailed list of the jobs following this typology.

Cities rely on different transport infrastructure and services. The availability of urban passenger services varies between countries and cities. Depending on the type of network available and its importance, the proportion of respective workers will vary. Urban passenger transport and related services include:

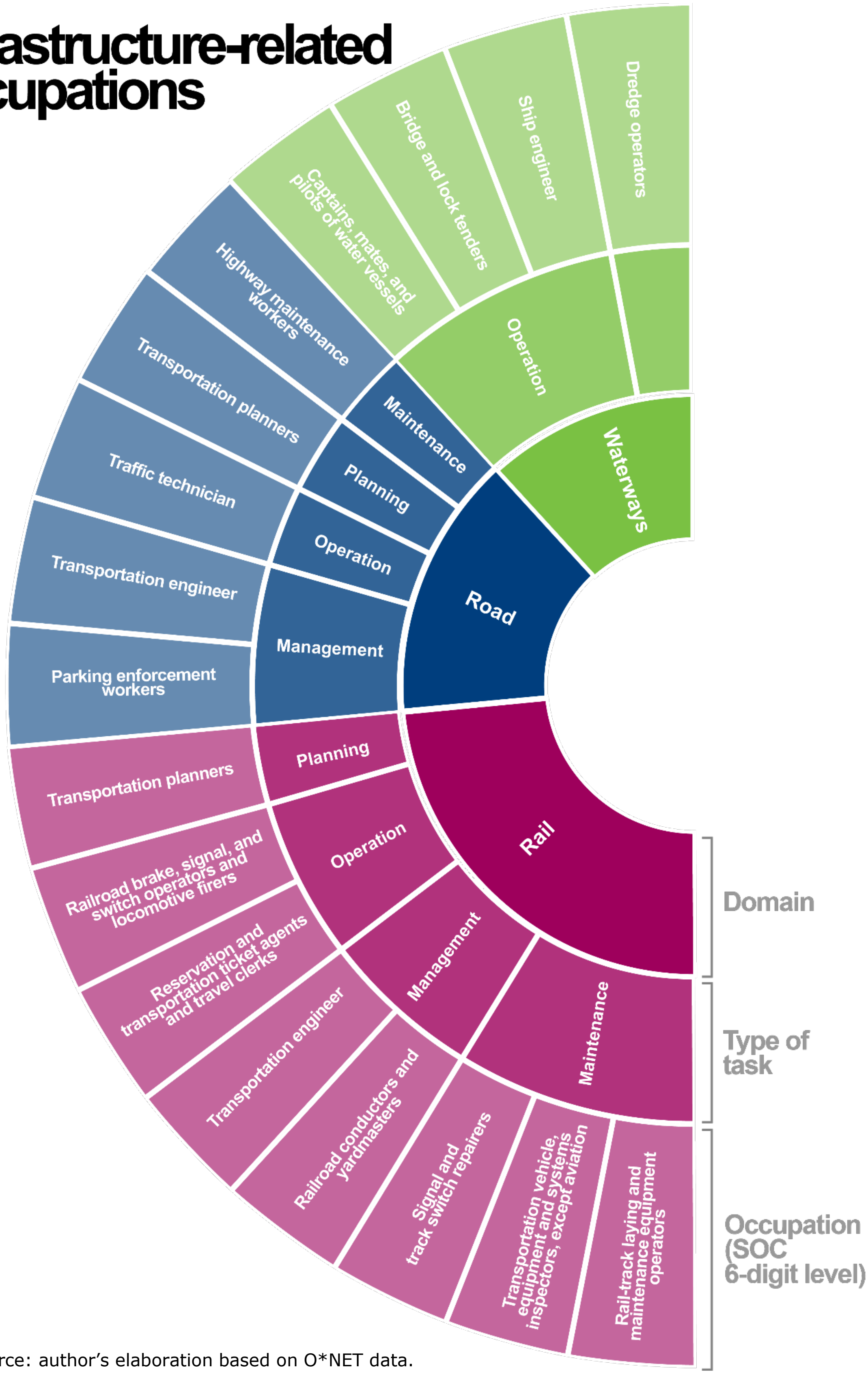
- road: taxis, buses, parking, shuttles, etc.
- rail: trams, light-rail, metro, trains, etc.
- waterways and ferries.

Figure 3. Urban passenger transport-related occupations by segment



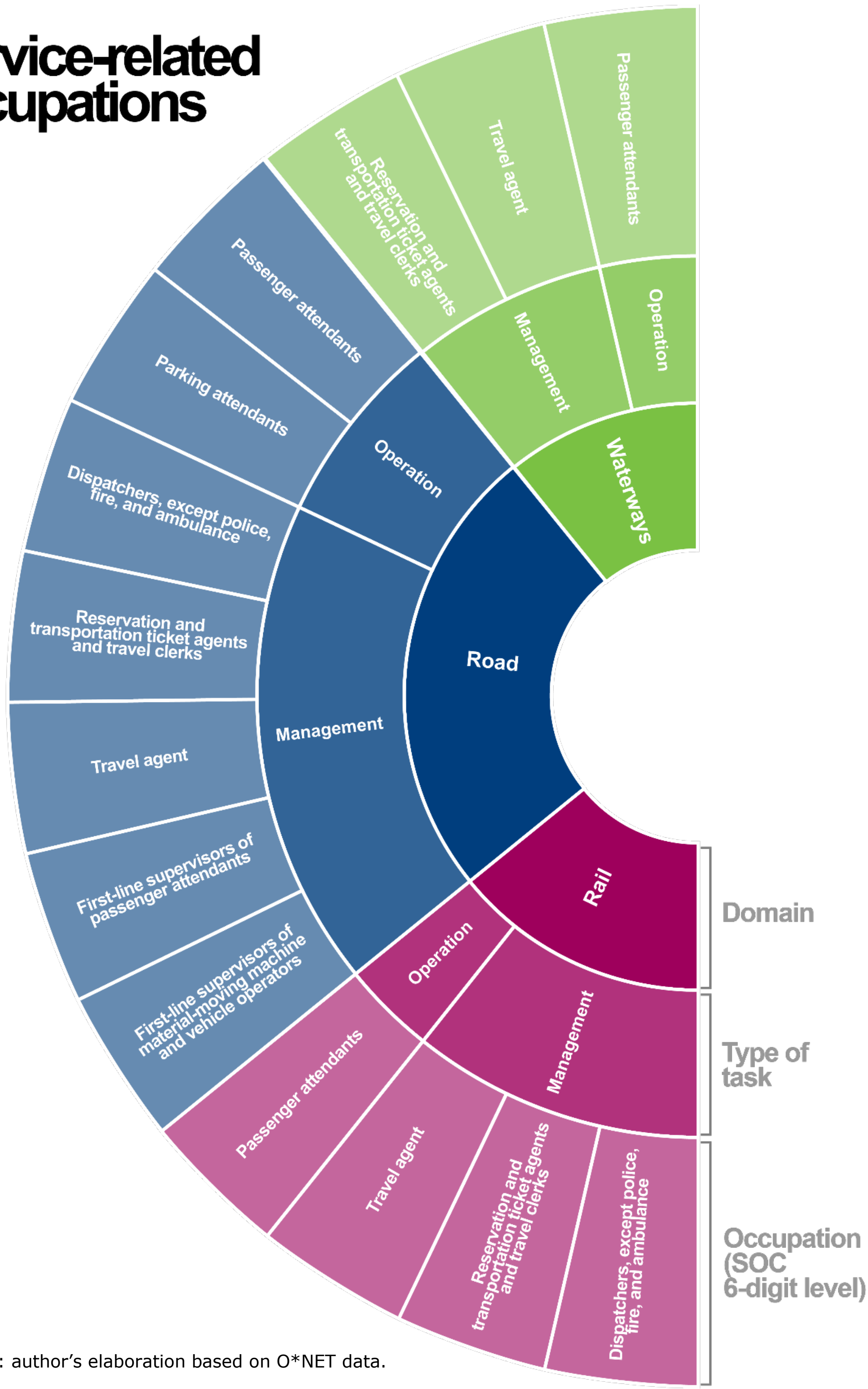
Source: author's elaboration based on O*NET data.

Infrastructure-related occupations



Source: author's elaboration based on O*NET data.

Service-related occupations



Source: author's elaboration based on O*NET data.

Assessing the automation of urban passenger transport

In urban areas, not all transport means are or can be easily automated due to the challenges posed by the complexity of the urban environment. This section examines the current role of automation in urban rail transport and metros, road vehicles and ferries.

Automated urban rail transport

Urban rail, especially the metro, is currently the most automated mode of urban passenger transport. The technology for automated train operation is widely available and fully automated. Unattended trains currently operate in many metro systems around the world. The first driverless metro lines started operating in the 1960s, and the first fully automated metros without attendants were launched in 1983 in Lille, France (Wang et al., 2016).

The level of automation in urban rail is well-defined by the International Electrotechnical Commission's (IEC) standard on urban railways (IEC, 2014). Based on how much the four major tasks for train operation – setting the train in motion, stopping the train, door closure and operation in the event of disruption – are conducted automatically, grades of automation (GoA) are assigned, ranging from GoA 1 to GoA 4. GoA 1 requires a driver for all four tasks. GoA 2 requires the driver's intervention in the event of disruption. Thus, while drivers are not required to drive the train all the time, they must be attentive to any potential disruptive events and tend to the door closure. From GoA 3, the operation does not require a driver to stay in the cabin. However, a train attendant is on the train to operate doors and respond to disruptive events. GoA 4 is called unattended train operation (UTO). It does not require any onboard staff.

Table 2. The International Electrotechnical Commission's grades of automation (GoA)

Grade of automation	Type of train operation	Setting train in motion	Stopping train	Door closure	Operation in the event of a disruption
1	ATP with driver	Driver	Driver	Driver	Driver
2	ATP and ATO with driver	Automatic	Automatic	Driver	Driver
3	Driverless	Automatic	Automatic	Train attendant	Train attendant
4	UTO	Automatic	Automatic	Automatic	Automatic

Note: ATP: Automatic Train Protection, i.e. computer-based equipment monitoring the safe running of trains to help the driver supervising its environment; ATO: Automatic Train Operation, i.e. computer-based system controlling the movement of the vehicle but driver can take over in the event of a disruption; UTO: Unattended Train Operation, i.e. fully automated train where no driver or attendant is controlling the train.

Source: IEC (2014).

According to UITP (2019a), the total length of automated metros in the world having GoA 4 level and a capacity of more than 100 passengers per train reached 1 000 km in March 2018. It represented 7% of the world's metro lines in operation. However, based on projects confirmed by 2018, automated metro lines are expected to reach over 3 800 km. From a labour perspective, UTO also allows staff to focus on more customer-oriented tasks rather than repetitive driving tasks. While capital expenditure on infrastructure could still be higher than conventional operations, the difference is getting smaller as more conventional lines are equipped with platform screen doors (PSD) and new facilities.

Automation in road transport

Compared to automated trains, the discussion of deploying AVs for urban transport only recently emerged, and their potential for transforming urban transport has been more widely anticipated. Numerous pilots have been initiated in many countries, and substantial technological advances have been made in the recent past. However, AVs have not yet reached the tipping point of being commercially available in any environment due to remaining technical and regulatory challenges.

Similar to the GoA levels for trains, there are levels of driving automation developed by SAE International that provide guidance about the degrees of automation and human roles corresponding to each level of automation (See Table 3).

Table 3. Human roles in different levels of driving automation

Level of driving automation	Human roles	
	In vehicle	Remote
0	In-vehicle driver	Remote driver (No driverless dispatcher or remote assistant roles as there are no automated driving system (ADS) to dispatch or assist)
1		
2		
3	In-vehicle fallback driver	Driverless dispatcher/remote assistant
	Passenger	Remote fallback driver Driverless dispatcher/remote assistant
4	Passenger	Driverless dispatcher/remote assistant (remote driver role is not required)
5		

Note: The area enclosed by red lines are the use cases not requiring an in-vehicle driver

Source: Adapted from SAE International (2021).

While AVs have the potential to transform urban transport services through new modes such as automated scheduled buses, automated shuttles and robotaxis, it is uncertain when these new modes will be widely available. Currently, most global vehicle manufacturers have released level 2 features as high-end options for their passenger vehicle line-ups. Some vehicles have functions to make lane changes while drivers' hands are on the steering wheel. Level 3 vehicles started to be released on the market in 2023 but with quite restrictive operational design domains (ODDs), which describe the conditions in which an automated system is designed to operate (i.e. infrastructure, weather conditions, time of the day, etc.) (Hawkins, 2023). From level 4, the automated driving system (ADS) takes full responsibility for all the driving tasks during the driving in the vehicle's respective ODDs. However, depending on the ODDs, the shapes and features of AVs could be widely different. Level 5 is more like a hypothetical ultimate level with limitless ODDs and the ability to drive in any road environment.

Issues such as cost, privacy, competition with automated private passenger cars and social acceptance need to be considered. Unlike urban railways, whose routes are relatively separate from outside environments, AV-based transport services would be visible in the urban environment, including passers-by. This could bring up privacy and security issues and affect the social acceptance of AV-based services.

Automated ferries

There have been pilot projects to test automated maritime ships and inland waterway navigation. However, automated ships for urban passenger transport are not yet as developed as automated road or rail transport. It is more likely that automation technologies will be applied to bigger maritime ships first and will then be expanded to smaller urban passenger ferries.

The International Maritime Organization's (IMO) maritime safety committee has provided a basic framework for the definitions and degree of automation on automated maritime ships (IMO, 2018) (see Box 2).

Box 2. The degrees of autonomy of Maritime Autonomous Surface Ships

IMO introduced the concept of Maritime Autonomous Surface Ships ("MASS"), which describes four degrees of automation:

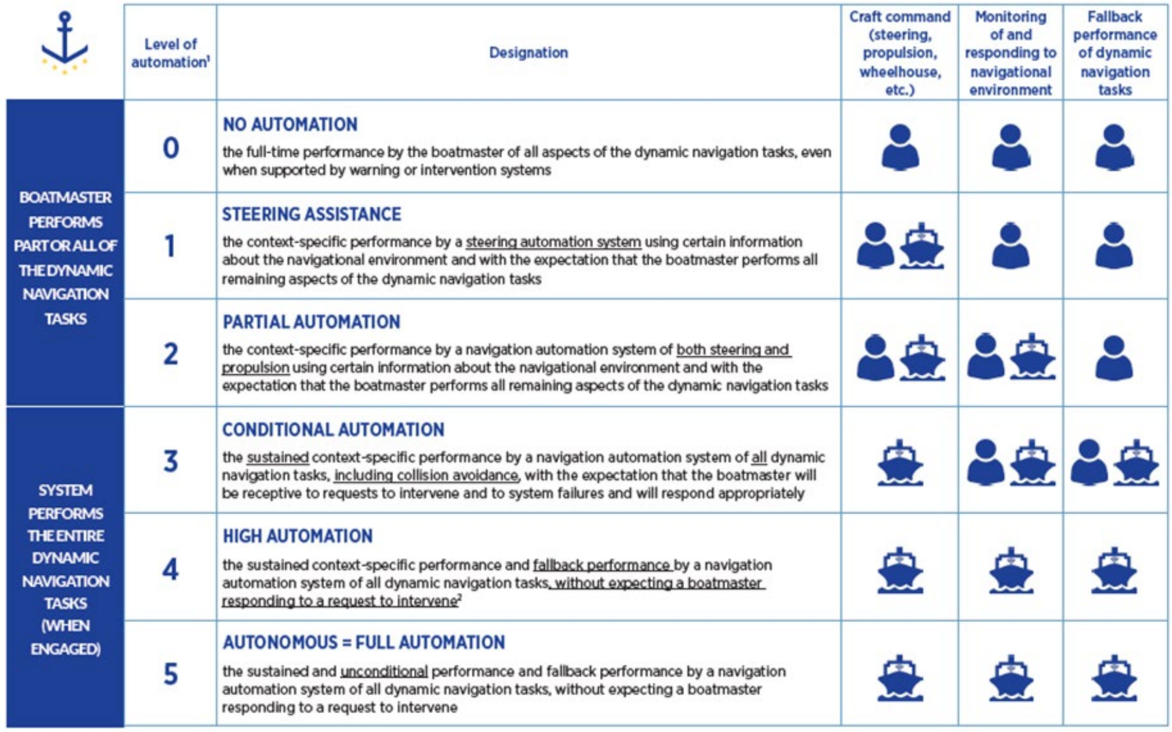
- Degree one: Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised, but with seafarers on board ready to take control.
- Degree two: Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.
- Degree three: Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.
- Degree four: Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself.

Source: IMO (2018).

While the IMO is more focused on international maritime shipping, the Central Commission for the Navigation of the Rhine (CCNR) has proposed levels of automation for inland navigation, which are similar to SAE International's levels for driving automation (Figure 4) (CCNR, 2018). The CCNR also provides authorisation procedures for pilot projects on the Rhine. As of April 2023, 40 projects are listed on the CCNR directory, of which 15 are at level 4 or above and do not require human intervention (CCNR, 2023). However, of the 40 projects, only one level 3 project concerned developing automated passenger ferries.

Using automated ships for urban passenger ferries would require addressing several issues related to navigational tasks and passenger safety. Thieme et al. (2023) presented these gaps based on a hypothetical highly automated passenger ferry operation under Norwegian regulation. It was assumed that a safety supervisor and a permanent crew were in the remote supervision centre and could reach the vessel in a few minutes. In such a situation, while most of the requirements can be met, an emergency such as fire, collision, evacuation, or injury treatment could be beset by challenges and require additional attention to ensure a rapid response.

Figure 4. Levels of automation in inland navigation



	Level of automation[1]	Designation	Craft command (steering, propulsion, wheelhouse, etc.)	Monitoring of and responding to navigational environment	Fallback performance of dynamic navigation tasks
BOATMASTER PERFORMS PART OR ALL OF THE DYNAMIC NAVIGATION TASKS	0	**NO AUTOMATION** the full-time performance by the boatmaster of all aspects of the dynamic navigation tasks, even when supported by warning or intervention systems			
	1	**STEERING ASSISTANCE** the context-specific performance by a steering automation system using certain information about the navigational environment and with the expectation that the boatmaster performs all remaining aspects of the dynamic navigation tasks			
	2	**PARTIAL AUTOMATION** the context-specific performance by a navigation automation system of both steering and propulsion using certain information about the navigational environment and with the expectation that the boatmaster performs all remaining aspects of the dynamic navigation tasks			
SYSTEM PERFORMS THE ENTIRE DYNAMIC NAVIGATION TASKS (WHEN ENGAGED)	3	**CONDITIONAL AUTOMATION** the sustained context-specific performance by a navigation automation system of all dynamic navigation tasks, including collision avoidance, with the expectation that the boatmaster will be receptive to requests to intervene and to system failures and will respond appropriately			
	4	**HIGH AUTOMATION** the sustained context-specific performance and fallback performance by a navigation automation system of all dynamic navigation tasks, without expecting a boatmaster responding to a request to intervene[2]			
	5	**AUTONOMOUS = FULL AUTOMATION** the sustained and unconditional performance and fallback performance by a navigation automation system of all dynamic navigation tasks, without expecting a boatmaster responding to a request to intervene			

[1] Different levels of automation may make use of remote control but different conditions to be defined by competent authorities might apply in order to ensure an equivalent level of safety.
[2] This level introduces two different functionalities: the ability of "normal" operation without expecting human intervention and the exhaustive fallback performance. Two sub-levels could be envisaged.

Source: CCNR (2018).

Factors affecting vehicle automation

As discussed, the extent of automation in passenger transport varies across different modes. Several factors affect these differences, including the physical operational environment, the institutional and regulatory settings, and political and social factors.

Physical environment and technology

One of the most distinct differences between different modes of transport is their operational environment. Urban railways operate in well-controlled built-up environments, on guiding rails, with passengers getting on and off at the designated stops, usually via elevated platforms. These elevated platforms provide separation between the passenger areas and the rails at stations. The platform screen doors (PSD) provide an additional layer of separation. The routes between stations are also usually separated from other traffic. Underground and elevated railways provide dedicated train routes, thus minimising potentially dangerous contact. The well-controlled nature of the physical environment has contributed to the earlier automation of urban railways.

Automated road vehicles must overcome more complex environments as they interact with all other road and public-space users, such as road vehicles, cyclists and pedestrians. Therefore, AVs must detect and identify objects around them and estimate their movements. In addition, routes sometimes change due to events such as road construction, crashes, marathons and festivals. Adverse weather could affect the visibility of sensors and road conditions. This complicated environment requires substantive sensor and computational capability for operation.

Automated ferries would have similar difficulties. They need to operate on waterways that are exposed to weather conditions and shared by other vessels. Controlling the motions of a ship on the water adds additional complexity for automation.

Institutional and regulatory arrangements

The physical operational environment and how the service is organised could affect the service provision of automated transport. For urban railways, passengers can only access the service at the stations. Even though the trains are operated without human attendants, the operation can be monitored from stations, and staff can assist passengers, even when trains stop between stations. Urban ferries have similar staffed station systems. However, there is no central monitoring system for urban buses and taxis in most cases. The drivers are supposed to steward the in-vehicle situations. Thus, for AV-based services, the service providers may need to set up new remote monitoring, remote assistance and emergency dispatch systems. This is a substantial change from conventional transport services, which will take time to be firmly established.

The other aspect is that there are not yet internationally agreed vehicle safety standards for level 4 automated vehicles. Unlike conventional features that require mechanical specifications, the automated driving function requires a verification and validation process and criteria for driving skills of automated driving systems. The World Forum for Harmonization of Vehicle Regulations (United Nations Economic Commission for Europe Working Party 29) has been working on developing international regulations for automated driving systems (UNECE, 2023), but it is uncertain when it will be provided. The absence of universally applicable technical standards would hinder the wider deployment of AV-based services. Until then, AV-based services will likely be provided as individual deployment projects are permitted by authorities. Some authorities, such as the California Public Utilities Commission (CPUC), now provide procedures for paid driverless deployment to make the process more standardised (CPUC, 2021).

Political and societal factors

Public and political acceptance of automated services vary across modes. Train crashes usually result in passenger casualties. However, road vehicle crashes could have more severe consequences for passers-by and other road users. When a person feels unsafe on an automated urban railway, that person can avoid the risk by not taking the line. However, if AV-based services are on the road, a person cannot eliminate the risk simply by not using them, as they could still be hit. Thus, a wider group of people are affected by safety concerns for AV-based services. To earn support, AV-based services may need to provide assurances to potential users and the wider public.

The other aspect that differs between modes is their impact on jobs. AV-based services could replace more driver jobs than urban railways. The number of road transport drivers is significantly higher than that of urban rail drivers. While train drivers are primarily employees of rail companies, for whom companies could assign different tasks or who could be reskilled by their employers, a substantive share of road drivers are self-employed. Therefore, the automation of vehicle-based transport services could face political opposition from those affected and their representative groups. When the technology is ready, there must be policies in place to minimise the social costs of the transition to AV-based services.

The changing nature of work: Risks and opportunities

Automation technologies can support productivity growth and deliver other benefits, such as improved job quality (wages, working conditions, etc.). However, worries over technological unemployment continue to loom large and have been heightened by the rapid development of artificial intelligence (AI).

Effects on employment levels

This section reviews the available evidence on how automation technologies have affected employment levels over recent decades. Looking at the urban transport sector, it then discusses which urban transport occupations are at the greatest risk of automation, including due to advances in AI. Lastly, it explores the ways in which automation technologies can be seen as an opportunity in urban transport, including their adoption in areas that face worker shortages.

Evidence on how technology impacts employment levels

Advances in AI technologies have reignited debates about the impact of technology on employment levels. Despite empirical evidence that past waves of technological advancement have not led to massive job loss, fears of technological unemployment persist. With AI, in particular, there is concern that previous sources of new employment growth are no longer as powerful, given the pace and scope of current technological advancement (Brynjolfsson and McAfee, 2016).

Researchers have adopted a range of approaches to study the link between technology and employment levels:

- proxy measures (e.g. industrial robots, automation technologies, AI technologies) to investigate whether occupations with greater exposure to a technology saw different patterns in employment levels and growth compared to less exposed occupations
- analysing employment trends among a subset of occupations expected to be at risk of automation
- survey evidence
- and case studies.

Investigating the impact of technological change on labour market outcomes using proxy measures is a response to a lack of direct measurement of automation technologies. In this category, Georgieff and Milanez (2021) used a measure of automation risk as a proxy for actual automation to analyse the impact of automation technologies on labour market outcomes. This research was in response to several papers that estimated automation risk in the mid-2010s, and which generated much attention for their foreshadowed impact on job levels (Arntz, Gregory and Zierahn, 2016a; Frey and Osborne, 2017; Nedelkoska and Quintini, 2018). It sought to take stock of whether automation risk was linked to recent changes in employment levels. The authors found that, while OECD countries have typically experienced increased employment levels over the past decade, employment growth has been lower in occupations at high risk of automation compared to those in low-risk occupations. Although there is no evidence of net job loss, slowed growth may be an indication of labour substitution in high-risk occupations, with firms choosing not to replace staff who retire or resign.

Investigating the impact of AI technologies in particular, Felten, Raj and Seamans (2019) created an occupation-level measure of AI exposure and considered changes in occupation-state employment and wage levels in the United States between 2010 and 2015. They found that, while an occupation's exposure to AI has a small positive link with wages, there is no link with employment. Extending the Felten, Raj and Seamans (2019) measure of AI exposure to 23 OECD countries, Georgieff and Hyee (2021) found no clear relationship between AI exposure and employment levels at the country level. However, looking within occupations, they observed that those with high AI exposure and whose jobs require intensive computer use (e.g. business professionals, legal, social and cultural professionals, managers, and science and engineering professionals) saw higher employment growth. This may suggest that workers with better digital skills (as proxied by computer use) may have a greater ability to adapt to and use new technologies at work and, as a result, reap the benefits that these technologies offer.

As part of the second approach, analysing employment trends among a subset of occupations expected to be at risk of automation, Handel (2022) analysed a set of occupations often cited as illustrations of technological displacement to see whether these occupations' employment trends since 1999 and projected to 2029 exhibit notable differences. Using US Bureau of Labor Statistics data for the occupations of interest, the author found little support for the idea of a general acceleration of job loss or a structural break with trends pre-dating the AI revolution.

The OECD recently undertook parallel surveys of workers and firms in the finance and manufacturing sectors in seven countries concerning the impact of AI on the labour market, including on employment levels (Lane, Williams and Broecke, 2023). The results from the employer survey indicated that most employers reported no change in employment levels due to AI (55% in finance and 52% in manufacturing). However, among those that reported a change, slightly more employers reported a decrease in employment rather than an increase. The results from the worker survey indicated that, among companies that had adopted AI technologies, 20% of workers in finance and 15% of those in manufacturing said that they knew someone in their company who had lost their job because of AI[2]. Together, the surveys offer evidence of some job loss associated with AI technologies in finance and manufacturing based on employers' and workers' reports.

Recent OECD work involved case studies of AI technologies implemented within firms in the finance and manufacturing sectors in eight countries and their impact on the labour market (Milanez, 2023). The results suggest that job loss due to AI technologies is not yet widespread. Job losses were reported in only a few of the 96 case studies analysed[3]. Where there was less need for human workers due to the introduction of an AI technology, workers were deployed to other areas of the firm or retained in their same positions until voluntary departures, such as through retirement. At the same time, the case studies did reveal evidence of slowed hiring, which foreshadows a possibility that the employment levels of some occupations may see decreases over time (following no growth and attrition).

While the existing evidence considering the impact of AI technologies does not provide strong evidence of widespread job loss so far, an important qualification is the possibility that the impact of AI may grow as technologies mature and AI adoption picks up. In the transport sector, in particular, a UK analysis found transport workers to be most vulnerable to job loss in the long term, as autonomous vehicle technology is expected to mature after 2030 (PwC, 2021).

Despite persistent fears of technological unemployment, research has also documented the fact that automation does not necessarily lead to job loss, even in the affected industry. When major industries automate, their employment often rises rather than falls (Bessen, 2019). This is due to the tendency for productivity-improving technologies to reduce prices in competitive markets, which could increase demand. If demand increases sufficiently, then employment will grow, though job gains may be temporary (Bessen, 2019).

Which jobs are at risk of automation in the urban transport sector?

In efforts to anticipate the extent to which jobs are susceptible to automation and where the impacts of technology will be felt, researchers have created occupation-level "risk of automation" measures that reflect an occupation's exposure to automation (Frey and Osborne [2017] for the United States; and Arntz, Gregory and Zierahn [2016b]; Nedelkoska and Quintini [2018] and Lassébie and Quintini [2022] for OECD countries). This section focuses on the risk of automation measure resulting from the most recent of these studies, Lassébie and Quintini (2022), which draws on recent expert assessments of the automatability of 100 skills and abilities, taking into account the latest progress in AI technologies and robotics, and covers 25 OECD countries[4,5].

A key finding of Lassébie and Quintini (2022) is that the SOC two-digit occupation categories[6] that face the highest automation risk are construction and extraction occupations; farming, fishing and forestry occupations; production occupations; and transport and material moving occupations, as shown in Figure 5. They account for an average of about 28% of employment across OECD countries[7]. While this finding shows that a high portion of jobs are exposed to automation, fewer are exposed to obsolescence. Even jobs that are at high risk of automation involve bottlenecks that cannot be completed by automated solutions[8]. A more detailed analysis, based on the automatability of skills and abilities, found that an average of 9% of workers are employed in occupations with at least 25% of highly automatable skills and abilities. This indicates that a smaller portion of workers face substantial risk of job reorganisation.

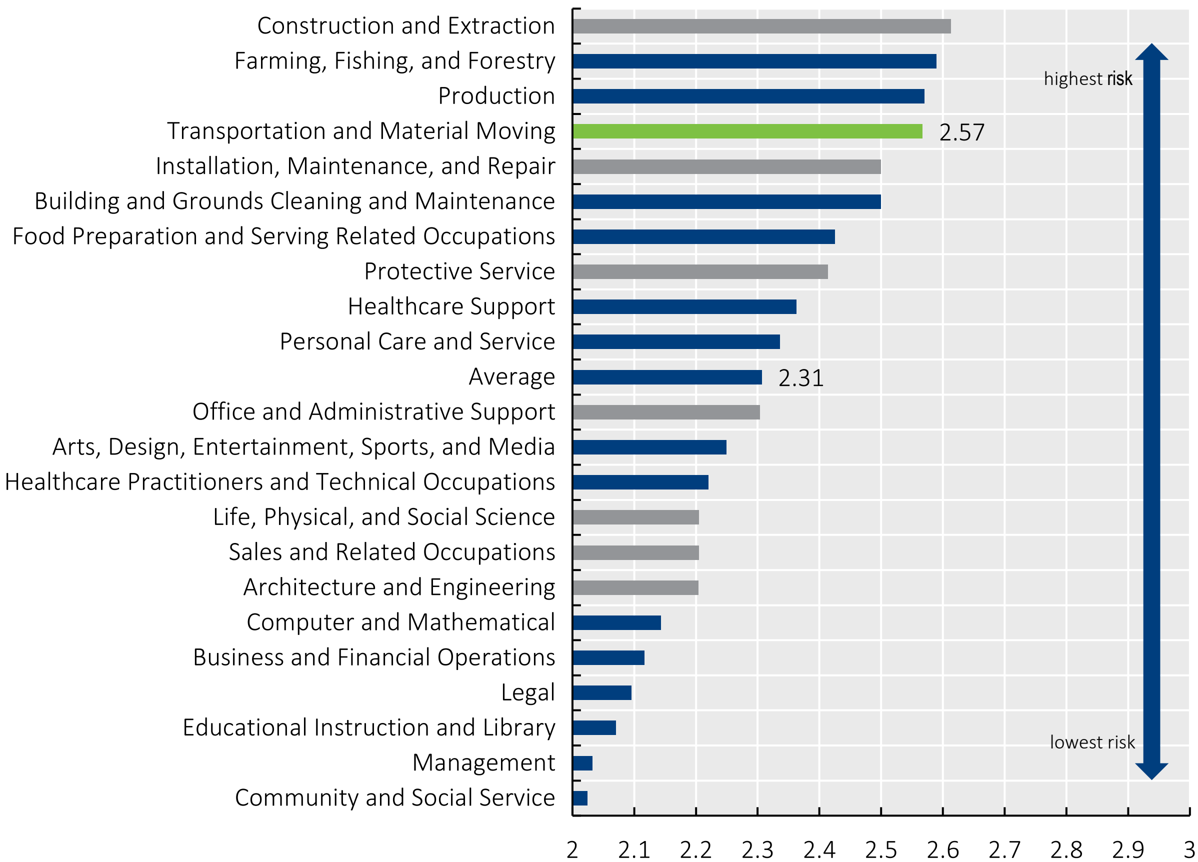
The portion of workers employed in occupations with significant shares of highly automatable skills and abilities varies substantially between countries: in the Czech Republic, Hungary, Latvia, Romania and the Slovak Republic, 12% to 18% of total employment is at high risk. Luxembourg, Netherlands, Norway, Sweden, Switzerland and the United Kingdom lie at the other end of the spectrum, with less than 6% of total employment at risk.

Across the labour market, transport occupations are at a relatively high risk of automation

Automation will affect occupations across the labour market unevenly. Occupations in the four categories mentioned rely on skills and abilities that are highly susceptible to automation (e.g. near vision) and little on skills and abilities that cannot be automated (e.g. assisting and caring for others). In contrast, other occupation categories, such as community and social service, management, educational instruction and legal, face lower automation risk, highlighting the uneven effect of automation across labour markets.

The most relevant SOC two-digit occupation category for the urban transport sector is "transport and material moving," as the largest share of urban transport workers are contained within it. The automation risk for transport and material moving occupations is 2.57, 11% above the average automation risk for all occupations of 2.31. While certain SOC two-digit occupation categories relevant to the urban transport sector are at an elevated automation risk[9], others are less exposed. On the other hand, other occupation categories relevant to the urban transport sector – office and administrative support; life, physical and social sciences; sales and related occupations; and architecture and engineering – are at a less than average risk of automation.

Figure 5. SOC two-digit occupations and their relative risks from automation



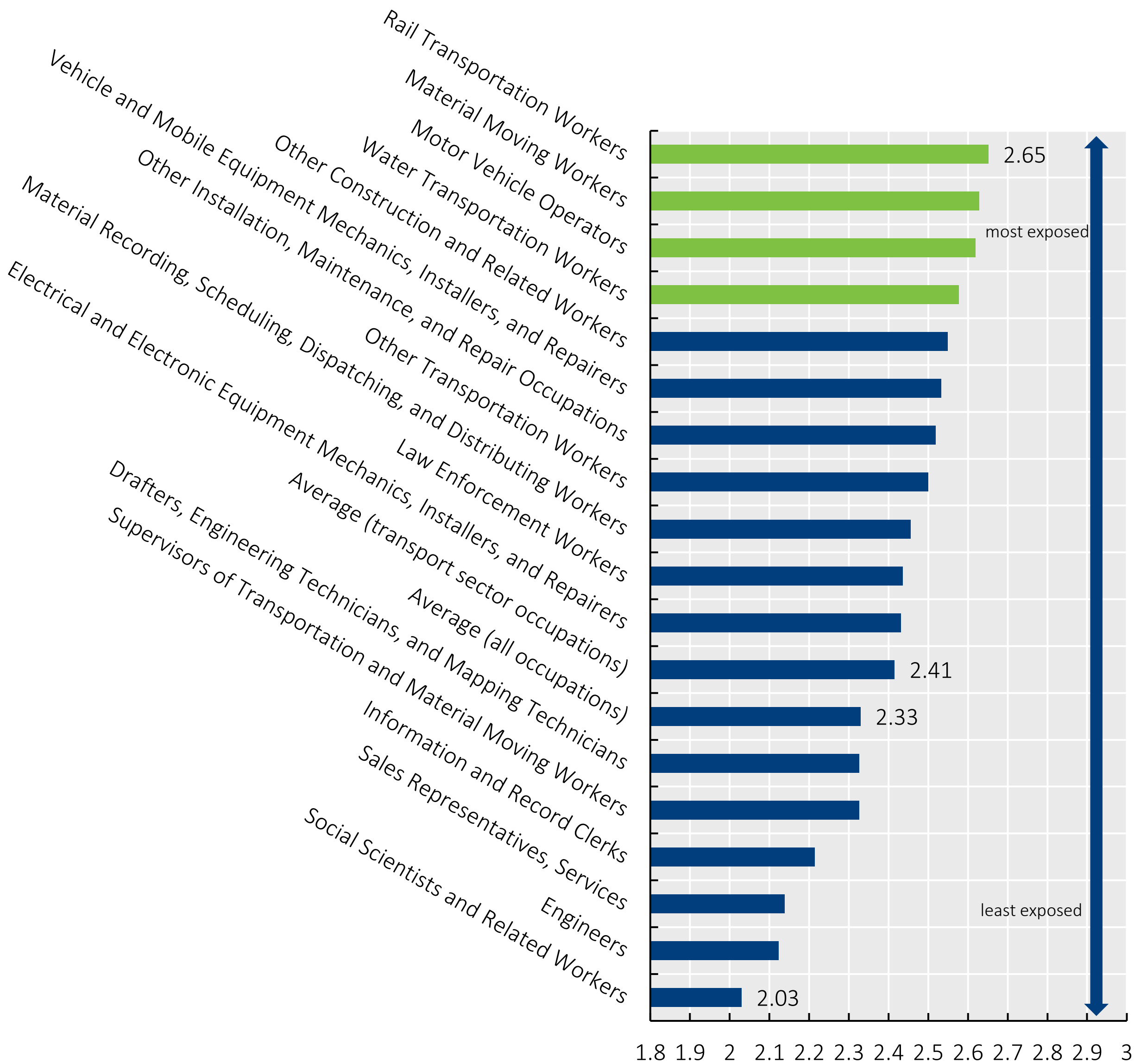
Note: Calculations are based on the OECD Expert Survey on Skills and Abilities Automatability and O*NET. The occupation categories are from O*NET.

Source: Lassébie and Quintini (2022).

The wide range of automation risk when looking at major occupation categories (SOC two-digit) points to the importance of looking in greater detail within the urban transport sector. For this, it is helpful to look at minor occupation groupings (i.e. defined at the SOC three-digit level) within the set of urban transport occupations as determined by the ITF using O*NET occupations. For example, the major occupation category "transport and material moving" contains the SOC three-digit occupational group "rail transport workers." At this greater level of granularity, occupations within the urban transport sector have an average automation risk of 2.41. Automation risk across minor occupation groups in urban transport ranges from 2.03 (social scientists and related workers) to 2.65 (rail transport workers). This is set against average automation risk across all occupations of 2.33 (with a standard deviation of 0.19). This indicates that while not all occupation groups in urban transport are at elevated automation risk relative to all jobs in the labour market, on average, urban transport jobs are more exposed.

As shown in Figure 6, certain occupations appear particularly exposed, including rail transport workers (e.g. subway and tram operators); material moving workers (e.g. cleaners of vehicles and equipment); motor vehicle operators (e.g. taxi drivers, bus drivers); and water transport workers (e.g. pilots of water vessels, ship engineers). In contrast, other urban transport workers are less exposed to automation risk, including sales representatives (e.g. travel agents), transport engineers and social scientists (e.g. urban planners).

Figure 6. Automation risk for occupations in the urban transport sector at the SOC three-digit level



Note: Calculations are based on the OECD Expert Survey on Skills and Abilities Automatability and O*NET. The occupations in green have an automation risk exceeding the 2.57 average for the Transport and Material Moving occupation (SOC two-digit level). The occupation categories are taken from O*NET.

Source: Lassébie and Quintini (2022).

Within urban transport, the automation risk is higher for vehicle occupations, maintenance occupations and operations occupations, but lower for planning occupations

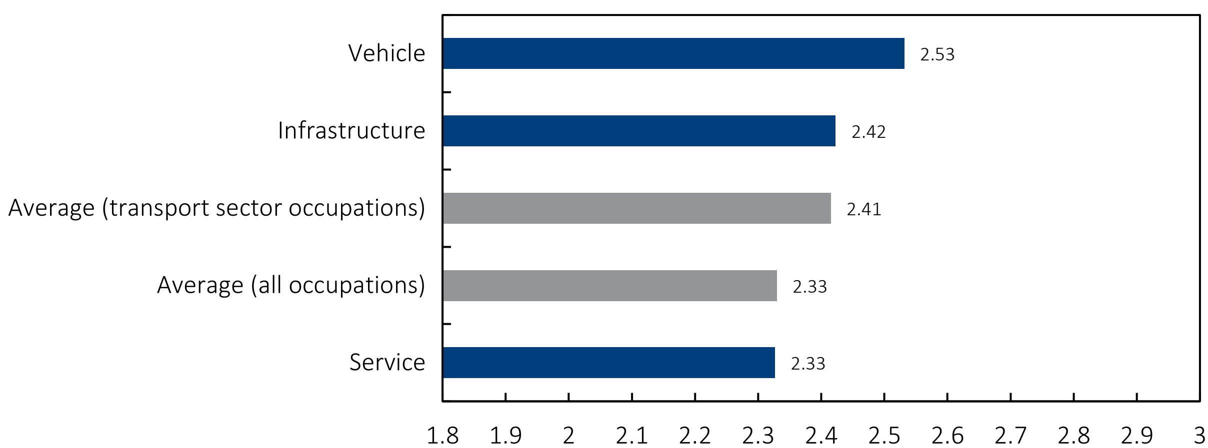
One means of assessing automation risk in the urban transport sector is to consider where jobs in the sector lie across different categories. As described above, urban transport jobs can be grouped according to three broad categories based on a typology developed by the ITF using O*NET occupation categories (see Figure 3):

- the segment of urban transport the job relates to (i.e. infrastructure, service or vehicle operation)
- the predominant role of the job (i.e. management, maintenance, operation or planning)

- the mode of transport the job relates to (i.e. waterway, rail or road).

Looking across different segments of the urban transport sector, vehicle occupations are at an elevated automation risk compared to infrastructure and service-related occupations. Figure 7 shows the average automation risk for occupations within different segments of urban transport categories: vehicle, service and infrastructure. The average automation risk across vehicle occupations is 9% higher than the average automation risk across all occupations in the labour market (2.53 compared to 2.33). Vehicle occupations concern operating, maintaining or servicing different modes of transport. They include bus drivers, sailors, taxi drivers, technicians, repairers and cleaners of vehicles. The higher automation risk among vehicle occupations stems from greater reliance on skills where automation technologies have made recent advances and are thus capable of substituting workers. Important skills in vehicle occupations that also carry a high automation risk include selective attention, reaction time, control precision, near vision and visual colour discrimination (see section "How automation changes skill needs").

Figure 7. Automation risks across the different segments of urban transport



Note: Calculations are based on the OECD Expert Survey on Skills and Abilities Automatability and O*NET. The occupation names are from O*NET. The averages were calculated using the risk of automation values for the occupations in each category (SOC three-digit level). The measure has a scale between 1 and 5 (low indicating low automation risk and vice versa).

Source: Lassébie and Quintini (2022).

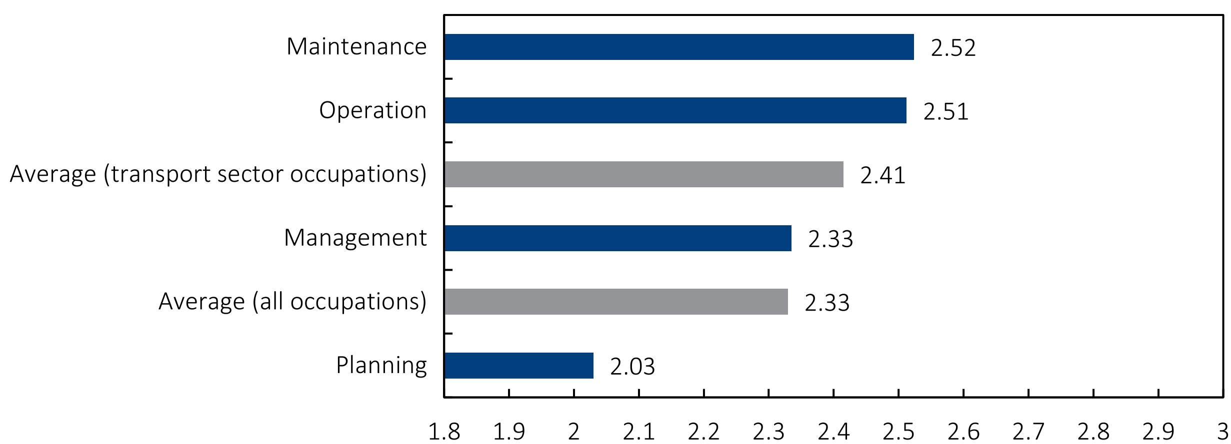
In contrast, service-related occupations are at lower automation risk. Service-related occupations share the same level of average automation risk as all occupations in the labour market (2.33). They include dispatchers, parking attendants, passenger attendants, reservation and transport ticket clerks, and travel agents. The lower automation risk among service-related occupations stems from greater reliance on skills used in interpersonal interactions, where humans maintain a comparative advantage. Important skills include speaking, expression and listening.

Infrastructure-related occupations – including dredge operators, highway maintenance workers and transport planners – face an automation risk slightly higher than the sector average. These occupations rely to some extent on skills with high automation risk, such as selective attention and near vision. However, they also rely on skills where humans maintain a comparative advantage, such as problem sensitivity (i.e. the ability to tell when something is wrong or is likely to go wrong), active listening and oral comprehension. The low automatability of these skills counterbalances those that carry a higher automation risk, resulting in a moderate automation risk for infrastructure-related occupations overall.

Automation risk by job role: Looking across different job roles, automation risk is greatest among maintenance and operation occupations and lowest among planning occupations. Figure 8 shows the average risk of automation for occupations within different task categories: maintenance, management, operation and planning. Average automation risk across maintenance occupations is 8% higher than average automation risk across all occupations in the labour market (2.52 compared to 2.33). Maintenance occupations are concerned with maintaining the condition of transport infrastructure and vehicles. They include highway maintenance workers, mechanics, signal and track switch repairers, cleaners of vehicles and equipment and robotics technicians, among others. The higher automation risk among maintenance occupations stems from greater reliance on skills at high risk of automation, such as selective attention, near vision, control precision, operations monitoring and information ordering.

Operation occupations are also at an elevated risk of automation (2.51). Operation occupations are concerned with operating different modes of transport, either in a direct capacity (e.g. bus, taxi and shuttle drivers, subway operators, sailors and railway conductors) or to aid the flow of transport (e.g. railway brake, signal and switch operators, traffic technicians, passenger attendants). Operation occupations rely on similar skills to maintenance occupations. In addition, they rely on skills related to motion, such as reaction time, arm-hand steadiness and perceptual speed, which are all areas in which automation technologies have made recent advances.

Figure 8. Automation risks for maintenance and operation occupations compared to management and planning occupations



Note: Calculations are based on the OECD Expert Survey on Skills and Abilities Automatability and O*NET. The occupation names are from O*NET. The averages were calculated using the risk of automation values for the occupations in each category (SOC three-digit level). The measure has a scale between 1 and 5 (low indicating low automation risk and vice versa). See Figure 3 for the complete list of occupations included.

Source: Lassébie and Quintini (2022).

Finally, management occupations are at average risk of automation (2.33), while planning occupations are at low risk (2.03). Management occupations include supervisors of vehicle operators, supervisors of passenger attendants and transport engineers. Important skills in these occupations include oral expression and comprehension, active listening, speaking, reading, written comprehension and scheduling work and activities, areas in which human workers maintain a comparative advantage. Human comparative advantages are even more evident in planning occupations, which have a 13% lower automation risk compared to occupations on average (2.03 versus 2.33). This category includes transport planners, who prepare studies for proposed transport projects. They gather, compile, and analyse data, study the use and operation of transport systems and develop transport models or simulations. Important skills for transport planners include active listening, complex problem-solving, critical thinking and oral expression, all of which are areas in which automation technologies are less advanced.

The two categories discussed so far – segment of the urban transport sector and job role – are not mutually exclusive. For example, a vehicle occupation can also be an operation occupation, such as subway and streetcar operators. If an occupation has an elevated automation risk in both job categories, its overall automation risk is even higher. This is true of vehicle operation occupations (e.g. captains, mates and pilots of water vessels; motorboat operators; sailors and marine oilers; locomotive engineers; train conductors and yardmasters; subway and tram operators; bus drivers; shuttle drivers and chauffeurs; taxi drivers). Vehicle operation occupations have an average automation risk 12% higher than all occupations (2.62 compared to 2.33). On the contrary, if an occupation has a reduced automation risk in both job categories, its overall automation risk is lower. This is true of service management occupations (e.g. reservation and ticket clerks; travel agents; dispatchers, except police, fire, and ambulance; first-line supervisors of material-moving machines and vehicle operators; first-line supervisors of passenger attendants). Service management occupations have an average automation risk of 2.29 compared to an average across all occupations of 2.33.

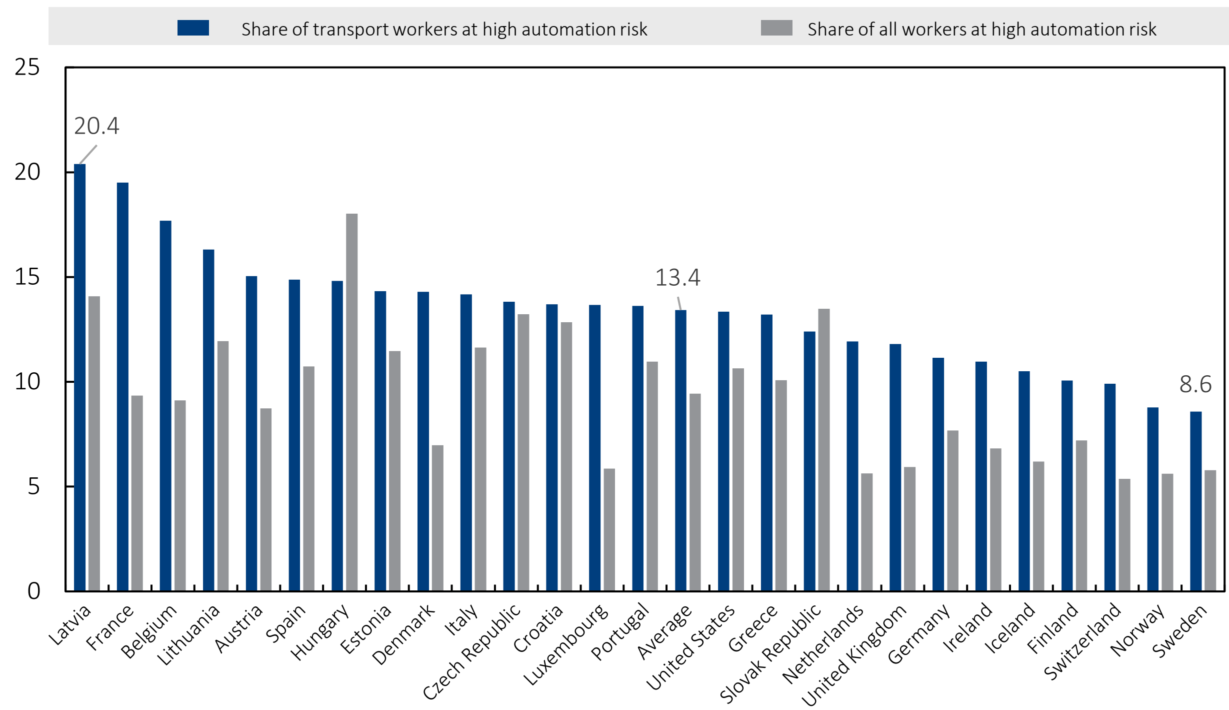
Automation risk by mode of transport: The third category analysed in the urban transport sector is mode of transport (e.g. waterway, rail or road). Automation risk does not vary much by the transport mode. The average automation risk for waterway occupations, rail occupations and road occupations is quite similar (2.42, 2.39 and 2.38, respectively, set against average automation risk for all occupations of 2.33). This is because the skills required by the jobs in each category are similar (both the high automation risk and low). For example, a skill with a high automation risk, such as perceptual speed, is equally important for pilots of water vessels, tram operators as well as taxi drivers. To take another example of a skill with a low automation risk, critical thinking is equally important for ship engineers, locomotive engineers and transport engineers. The use of logic and reasoning to identify the strengths and weaknesses of different approaches to problems characterises each of these roles (e.g. in the design of emergency procedures). Moreover, certain occupations cut across all modes of transport. For example, calibration technologists are required for ferries, rail and road to adapt procedures to calibrate measurement devices and perform preventive maintenance on equipment. Robotics technicians and travel agents are also found across all three transport modes.

Countries vary widely in the share of transport workers at high risk of automation

Looking across the 25 OECD countries covered by Lassébie and Quintini (2022), an average of 10% of the workforce is in occupations at high risk of automation (i.e. those for which more than 25% of important skills and abilities can be replicated by technologies)[10]. Figure 9 shows the share of employment in occupations at high risk of automation by country for all sectors and for the transport sector. The transport sector has a greater share of workers in high-risk occupations compared to all sectors combined, with around 13% of the transport workforce at high risk compared to around 10% of the workforce overall. This indicates that, in most countries, workers in the transport sector tend to be more exposed to automation technologies compared to workers in other sectors of the economy.

There are substantial differences between countries. Figure 9 shows that in Latvia, France, Belgium, Lithuania and Austria, more than 15% of employment in the transport sector is at high risk. Sweden, Switzerland and Finland lie at the other end of the spectrum, with less than 10% of transport employment at risk. In only two countries – Hungary and the Slovak Republic – the share of transport workers at high risk is lower than the share of total workers at high risk. This indicates that workers in transport are relatively less exposed than workers in other sectors in those countries. A full examination of the factors driving the variation in exposure to AI is beyond the scope of this study. Potential explanations could include differential existing levels of automation (i.e. some tasks in low-exposure countries may already be automated), different features of urban transport in different countries (i.e. more or less private car use) or different composition of occupations, which may impact exposure to automation.

Figure 9. Share of workers at high risk of being replaced by automation across countries



Source: Lassébie and Quintini (2022).

Potential opportunities in urban transport

Technological change also presents new opportunities for the urban transport sector. First, there is the prospect of new task and job creation as technologies create new roles for humans. Second, there is the possibility that automation technologies will be adopted and used in segments plagued by labour shortages. The automation of certain tasks within urban transport may be particularly beneficial in countries where demographic change is forecast to lead to even greater labour shortages.

New task and job creation

Some economists suggest that new task and job creation due to technological change will be an antidote to the tasks and jobs lost, as has happened in previous technological revolutions. For example, as mentioned above, in the context of autonomous vehicles, there is the growing occupation of safety drivers who provide human supervision to ensure operational safety. The OECD surveys of employers on the impact of AI technologies on the workplace demonstrated evidence of task creation (Lane, Williams and Broecke, 2023). In the two sectors of focus (manufacturing and finance) across seven countries (Austria, Canada, France, Germany, Ireland, the United Kingdom and the United States), half of employers in each sector reported that AI had created tasks that were not previously done by workers.

New task creation may also be happening in the transport sector. While an evaluation of new task and job creation in transport is beyond the scope of the current study, this would be a potentially important area for future research. In urban transport, new jobs may include self-driving fleet technicians, safety drivers, rider support operators and software engineers (Nunes, 2021).

In the meantime, employment projections can help to shed light on future employment trends in urban transport. Future employment estimates from the European Centre for the Development of Vocational Training (Cedefop) indicate that employment in land transport across EU-27 countries is expected to grow modestly between 2025 and 2035 (at 2% over the next ten years, matching the growth rate expected across all sectors)[11]. However, it is expected to be higher in some European countries, such as Luxembourg (29%), Denmark and Finland (16%), Romania (15%) and Ireland (14%).

According to the Bureau of Labor Statistics (BLS), employment projections for the United States, employment in urban transport occupations is projected to grow about 13% between 2020 and 2030, faster than the 8% average for all occupations. The occupation of passenger-vehicle drivers, with the exception of transit and intercity bus drivers, is projected to have the fastest employment growth (26%) compared to other occupations within the category of urban transport. The BLS expects employment growth for passenger-vehicle drivers to come, in large part, from demand for ride-hailing services (Tate, 2022). Thus, this is one example whereby technological change appears, at least anecdotally, to be associated with increased labour demand.

While technological change may lead to new job creation, the distribution of new jobs may be uneven. There is a risk that new jobs could be concentrated in large firms (which may be better able to invest in AI) and countries with education and training programmes to facilitate the acquisition of necessary skills (to benefit from the new tasks created). Workers in small firms or countries that do not keep up with the pace of innovation may be left with fewer employment opportunities. The impacts of AI job generation may, therefore, be very heterogeneous across countries, cities and sectors.

Alleviating labour shortages

Automation technologies may help to alleviate labour shortages in the urban transport sector. As mentioned above, the transport sector is characterised by labour shortages in many countries, with high shares of older workers in certain occupations, such as vehicle operation, as well as challenges hiring younger workers. In such cases, population age may add to these challenges. Shortages may be further exacerbated by ageing trends in certain countries that will increase demand for public transport or additional para-transit transport services. By 2050, at least one-quarter of the global population, except Africa, is expected to be 60 years of age and above (UN Department of Economic and Social Affairs, 2015).

In addition, the COVID-19 pandemic brought about labour shortages that have been particularly persistent in certain sectors, including transport (Causa et al., 2022). Between the end of 2019 and the end of 2021, job vacancies outpaced hiring in the transport sector in the Czech Republic, Finland, France, Lithuania, Slovenia and United States. These labour shortages have continued to persist in the urban transport sector. For example, in the United States, 96% of public transit system agencies surveyed in March 2022 indicated that they are experiencing labour shortages (APTA, 2023). In France, a shortage of public transport network drivers has led to service disruptions (RFI, 2022). To this end, the automation of tasks, though sometimes perceived as undesirable, could benefit the urban transport sector as a whole, improving service quality and costs for consumers.

How automation changes skill needs

Technological advances are steadily expanding the sets of skills and abilities in which machines may rival and even exceed humans. Thus, understanding how technological change is impacting skill needs is key to understanding how it will impact the future of work. This section reviews some evidence of how automation technologies have changed skill needs over recent decades. It then focuses on the urban transport sector and the urban transport skills that are at greatest risk of automation[12] and those less so. Lastly, it explores the ways in which automation technologies can be seen as an opportunity in urban transport due to the ways in which they can help address skill shortages.

How technology impacts skill needs

Jobs encompass numerous tasks. As the introduction of a new technology will impact some tasks but not all, examining changes to tasks within jobs is a commonly used framework for understanding the impact of technology on employment. One approach to assess the automatability of job tasks relies on expert surveys to directly estimate the extent to which technologies can replicate human skills and abilities[13]. Lassébie and Quintini (2022) find that recent technological advances have made some skills and abilities more susceptible to automation. For example, artificial intelligence (AI) technologies have made significant inroads when it comes to the knowledge of fine arts and psychomotor abilities (e.g. the ability to work in cramped workspaces and awkward positions, finger dexterity and manual dexterity). Automation technologies have also made advances in reading comprehension, deductive and inductive reasoning skills, fluency of ideas and scheduling skills, all of which make high-skilled jobs more susceptible to automation. However, significant bottlenecks to automation remain. For example, given the current state of technological developments, skills such as complex problem-solving, high-level management and social interaction cannot be automated.

Lassébie and Quintini (2022) also emphasise that most occupations rely on a combination of both "bottleneck" skills (i.e. skills where automation technologies cannot yet replace human workers) and highly automatable skills and abilities. For example, looking at the skill sets of the most at-risk occupations, they estimate that 18-27% of skills and abilities are highly automatable while 5% are bottleneck skills (where the experts consulted do not believe that automation technologies can replace human workers). Looking at the skill sets of the least at-risk occupations, they estimate that 5-10% of skills and abilities are highly automatable, while around 25% are bottleneck skills. Thus, the complete obsolescence of occupations is unlikely. Instead, jobs will be reorganised around different sets of tasks requiring different underlying skills.

To support workers in their transition to jobs that require different skill sets, some employers provide training. Evidence from worker surveys of AI in the workplace found that more than half of AI users said that their company had provided or funded training so that they can work with new technologies (Lane, Williams and Broecke, 2023).

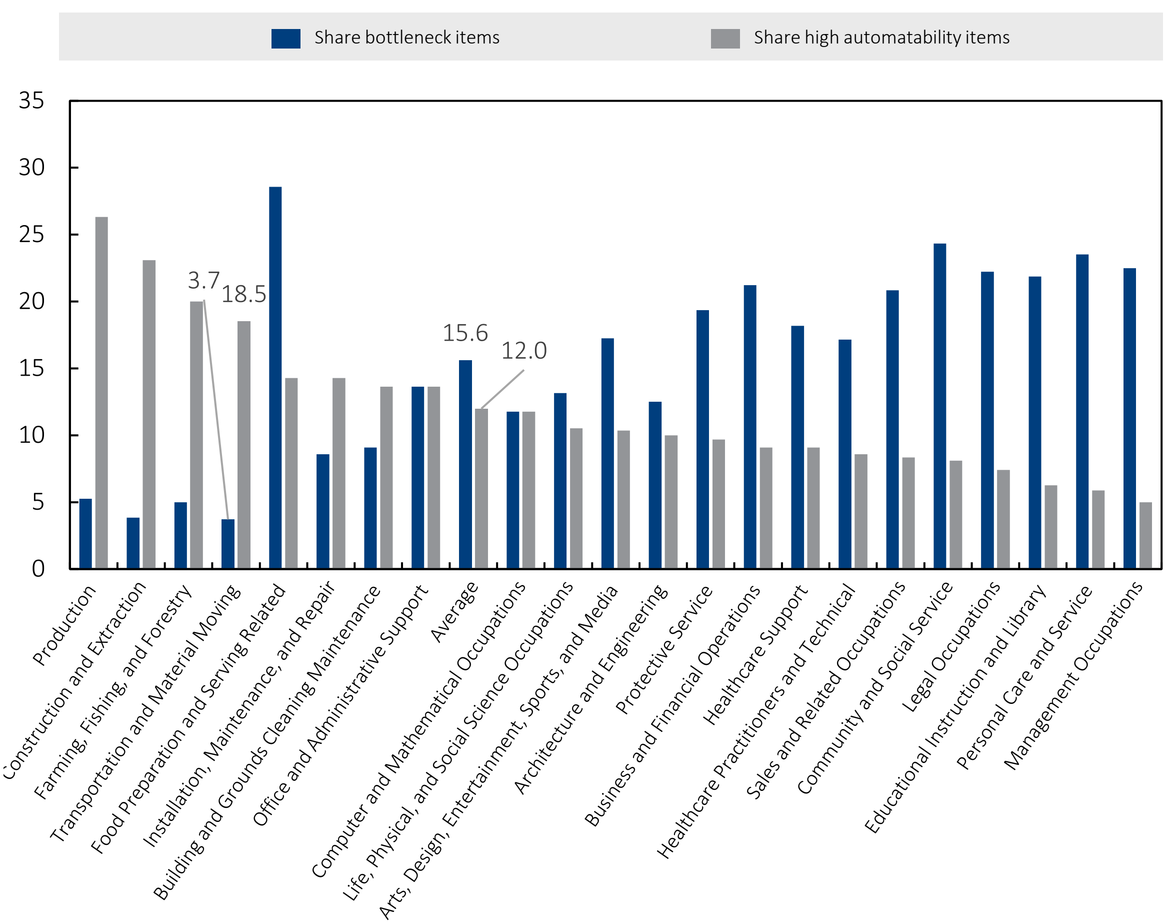
Which skills in the urban transport sector are at risk of automation?

This sub-section relies on the measure created by Lassébie and Quintini (2022) to analyse the extent to which skills in the urban transport sector are exposed to automation. It then discusses which skills are particularly exposed and which are less so in order to understand which skills will be important to the future of work in urban transport.

Transport skills are at a relatively high risk of automation

One means of assessing the automation risk facing different occupation categories is to compare the share of skills that are highly automatable to the share of bottleneck skills. The occupation categories with large shares of highly automatable skills compared to shares of bottleneck skills are production, construction and extraction, farming, fishing and forestry, and transport and material moving, as shown in Figure 10 (Lassébie and Quintini, 2022). Jobs within these categories are likely to have to adapt more radically to technological change than jobs in categories with greater shares of bottleneck skills, such as management, personal care and service, educational instruction and legal.

Figure 10. Share of highly automatable skills and bottleneck skills by occupation



Note: Calculations are based on the OECD Expert Survey on Skills and Abilities Automatability and O*NET. The occupation categories are from O*NET.

Source: Lassébie and Quintini (2022).

The category of transport and material moving occupations has the fourth-highest share of highly automatable skills. In this occupation category, 18.5% of skills are highly automatable. This is against an average of 12% across all occupations with a standard deviation of 5.5%. Transport and material moving occupations also have one of the smallest shares of bottleneck skills (3.7% against an average of 15.6% with a standard deviation of 7.2%). These two features together – a relatively large share of highly automatable skills and a relatively low share of bottleneck skills – suggest that these occupations could experience substantial change in the coming decades on account of advances in technological capabilities.

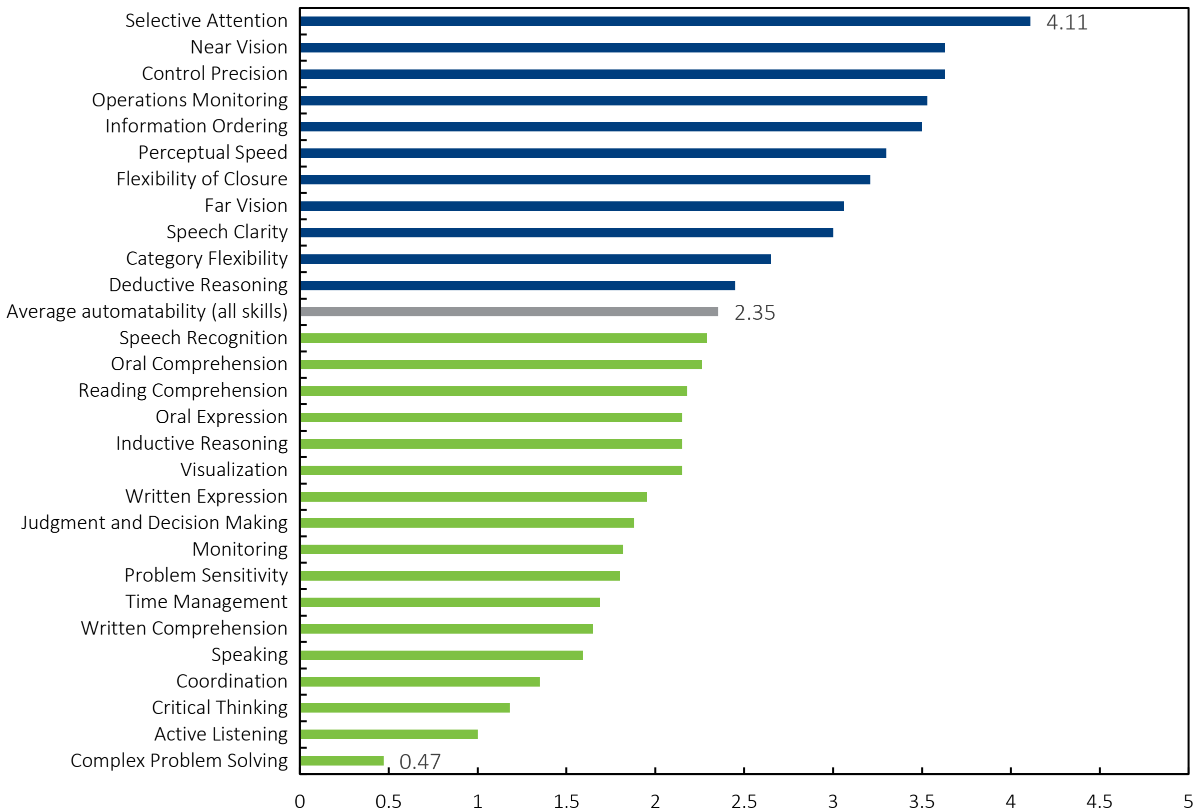
Not all occupations in the urban transport sector have the same skill profile as jobs in the category of transport and material moving occupations. Though most of the jobs within urban transport are found within this category[14], other occupations in the sector lie outside of it and have skill profiles that indicate somewhat less risk of automation. For example, urban transport jobs are also contained in the categories of protective service, office and administrative support, life, physical and social sciences (e.g. transport planners), sales and related occupations as well as architecture and engineering. These categories all have shares of bottleneck skills that exceed shares of highly automatable skills. This suggests that, on balance, the skill profiles of these occupations are less susceptible to automation because technology is as yet less capable in these areas. For example, the category of protective service contains the occupation of parking enforcement workers. 19.4% of protective service skills are bottleneck skills compared to 9.7% highly automatable skills, which indicates that the task mix of parking enforcement workers may be less susceptible to automation. Reservation and transport ticket agents and travel clerks appear even less susceptible, being composed of 20.8% bottleneck skills and 8.3% highly automatable skills.

Automation risk is higher for physical abilities and lower for cognitive skills

The wide range in the shares of bottleneck skills and highly automatable skills across SOC two-digit occupation categories points to the importance of looking in greater detail within the urban transport sector at which skills are highly automatable and which are less so. Figure 11 shows the automatability of skills that are important to occupations in the urban transport sector[15]. Among the skills required in urban transport, automation risk is highest for physical skills and abilities linked to vehicle operation and maintenance. These include selective attention, near vision, control precision, operations monitoring and information ordering. Table 4 below provides more detail on the definitions of the five skills and abilities with the highest automatability and the five with the lowest.

Selective attention is the skill with the highest automatability measure, at 4.11, compared to an average across all skills of 2.35 (with a standard deviation of 1.05). It describes the ability to concentrate on a task over a period without being distracted (e.g. studying a technical manual while listening to loud construction sounds). For humans, selective attention is a honed skill, and different senses are prone to interfere with the ability to focus. Technology, in contrast, is programmed for a single purpose, e.g. machine vision, and thus does not have the same interference problem as humans. Across all occupations, selective attention is highly important for air traffic controllers and airline pilots. In urban transport, it is important for locomotive engineers, motorboat operators and robotics technicians. Technological advancement in selective attention may lead to improved safety in urban transport, as automation technologies may outperform humans in this skill and are not susceptible to fatigue.

Figure 11. Automatability of skills in the urban transport sector



Note: Calculations are based on the OECD Expert Survey on Skills and Abilities Automatability and O*NET. The skills are from O*NET. The grey bar represents the average automatability among all skills, the green bars represent below average automatability and the blue bars indicate skills for which the automation risk is above th average for all skills.

Source: Lassébie and Quintini (2022).

At the other end of the spectrum, among the skills required in urban transport, automation risk is lowest for cognitive skills that are important to service occupations and management occupations. These include complex problem-solving, active listening, critical thinking, co-ordination and speaking, among others.

Complex problem solving is the skill with the lowest automatability measure, at 0.47, compared to the average across all skills of 2.35 (with a standard deviation of 1.05). It describes the ability to identify complex problems and review related information to develop and evaluate options and implement solutions (e.g. develop a plan to provide emergency relief for a major metropolitan area). Of all skills and abilities, complex problem-solving appears to be especially human. It draws on developed capacities to solve novel, ill-defined problems in real-world settings. This is not an area where automation technologies have made large advances so far due to the numerous exceptions that may arise. Across all occupations, complex problem-solving is highly important for chief executives and judges. Within urban transport, it is important for automotive engineers, transport engineers and transport planners.

Table 4. Most and least automatable skills required in urban transport occupations

Five most automatable skills and abilities in urban transport	
Selective attention	The ability to concentrate on a task over a period without being distracted
Near vision	The ability to see details at close range (within a few feet of the observer)
Control precision	The ability to adjust the controls of a machine or a vehicle quickly and repeatedly to exact positions
Operations monitoring	Watching gauges, dials, or other indicators to make sure a machine is working properly
Information ordering	The ability to arrange things or actions in a certain order or pattern according to a specific rule or set of rules (e.g. patterns of numbers, letters, words, pictures, mathematical operations)
Five least automatable skills and abilities in urban transport	
Complex problem solving	Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions
Active listening	Giving full attention to what other people are saying, taking time to understand the points being made, asking questions as appropriate and not interrupting at inappropriate times
Critical thinking	Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions, or approaches to problems
Co-ordination	Adjusting actions in relation to others' actions
Speaking	Talking to others to convey information effectively

Source: Based on O*NET data.

Skills required for vehicle operation and maintenance are at greatest risk of automation

One means of assessing changing skill needs in urban transport is to consider the skills most exposed to automation and those less so across the three categories of the sector: the segment of urban transport the job relates to (i.e. infrastructure, service or vehicle operation); the role that predominates in the job (i.e. management, maintenance, operation or planning); and the mode of transport the job relates to (i.e. waterway, rail or road). The results suggest that skills required in vehicle operation and maintenance jobs are the most automatable, foreshadowing the likelihood of larger change for the occupations that draw on these skills. In contrast, skills required in service, management and planning jobs are less automatable, suggesting that the occupations that draw on these skills are less susceptible to task reorganisation.

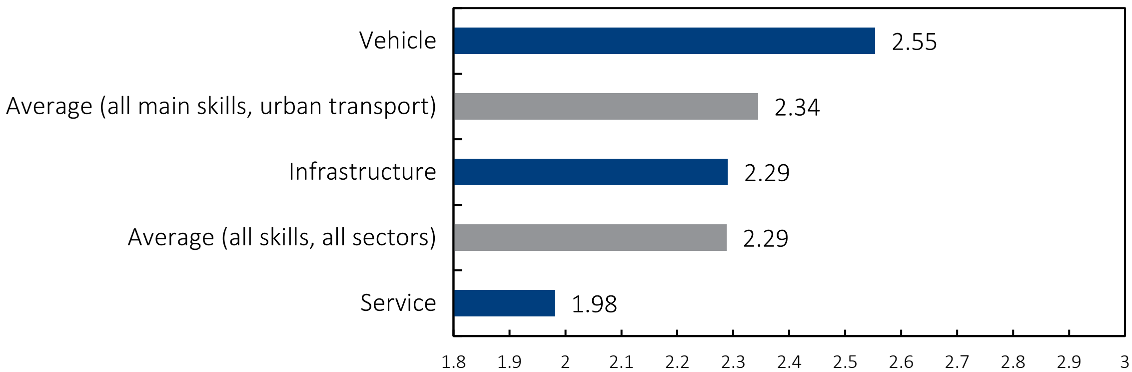
Skill automation risk by segment of the urban transport sector

Looking across different segments of the urban transport sector, skills required in vehicle occupations are at an elevated automation risk compared to skills required in infrastructure- and service-related occupations. Figure 12 shows the average automation risk for skills required within the vehicle, service and infrastructure segments of urban transport. Skills required in vehicle occupations have a higher average automation risk (2.55 compared to an average for all important skills in urban transport of 2.34 and an average across all sectors of 2.29, with a standard deviation of 1.04). Skills highly susceptible to automation in vehicle occupations include selective attention, reaction time, control precision, near vision, visual colour discrimination, operations monitoring and information ordering. Vehicle operation occupations draw upon only two bottleneck skills: active listening and repairing.

Service occupations, on the other hand, draw upon a greater number of bottleneck skills. Reflecting less susceptibility to automation, skills required in service occupations have a lower average automation risk

(1.98 compared to an average for all important skills in urban transport of 2.34). Bottleneck skills in service occupations include social perceptiveness, assisting and caring for others, service orientation and active listening. As a result, service jobs are less susceptible to change by automation technologies relative to other jobs in the urban transport sector.

Figure 12. Average automation risk for various urban transport occupations



Note: Calculations are based on the OECD Expert Survey on Skills and Abilities Automatability and O*NET.

Source: Lassébie and Quintini (2022).

Skill automation risk by job role

Looking across different job roles, automation risk is greatest among skills required for maintenance and operation occupations and lowest among skills required in planning occupations. Skills required in operation occupations and skills required in maintenance occupations have a higher average automation risk (2.47 and 2.41, respectively, compared to an average for all main skills in urban transport of 2.34). Highly automatable skills required in operation occupations are similar to those required in vehicle occupations: selective attention, reaction time, near vision, control precision, operations monitoring and information ordering. However, operation occupations rely on two bottleneck skills that are less important in vehicle operations: social perceptiveness and service orientation.

On the other hand, management and planning occupations require many bottleneck skills, such as complex problem-solving, social perceptiveness, service orientation, active learning, active listening and persuasion. In addition, transport planners require originality and the ability to manage staff, skills with only a slight risk of automation. As a result, skills required in management and planning occupations have a low average automation risk (2.03 and 1.92, respectively).

Skill automation risk by mode of transport

The third category analysed in the urban transport sector is mode of transport (i.e. waterway, rail and road). Looking across different transport modes, the automation risk is greatest among skills required for waterway and rail occupations and lowest among skills required for road occupations. However, the differences are modest. Skills required in waterway occupations and skills required in rail occupations have a higher average automation risk (2.56 and 2.50, respectively, compared to an average for all main skills in urban transport of 2.34). While waterway and rail occupations differ substantially in some ways, the skills required across the two categories are highly similar. Problem sensitivity, control precision, and operations monitoring are the most important skills in both occupation categories. In both, selective attention, reaction time and control precision are the most automatable skills.

Skills required in road occupations are at a lower average risk of automation. However, this result is based on the exclusion of certain skills deemed unnecessary for road occupations but required in waterway and rail occupations. Skills excluded in road occupations but included in the other categories include control precision (i.e. the ability to adjust the controls of a vehicle quickly and repeatedly) and reaction time (i.e. the ability to quickly respond to a signal when it appears). However, these skills could also be considered necessary for road occupations. The analysis of skills by category depends upon the completeness of occupation profiles in the O*NET database. A brief examination of road occupations in O*NET reveals that some road occupations (e.g. bus drivers, shuttle drivers and chauffeurs, and taxi drivers) are only partially complete, with data collection underway at the time of writing. Thus, the lower average automation risk of skills required in road occupations may be driven by incomplete data.

Future skill needs in urban transport

The discussion above has highlighted that many of the tasks and skills required in urban transport are likely to change in the coming years. While the evidence suggests that the need for adjusted-skill mixes is heterogenous across different occupations in the sector, there does seem to be a high exposure of certain tasks and skills to automation on average in the sector. The skill needs in the urban transport sector are likely to change substantially, meaning that policies that can align skill demand and supply are particularly important.

Improving the alignment between the skills required by employers and those of workers is, however, increasingly challenging. Not only are digitalisation, globalisation and rapid population ageing continuing to affect the supply and demand for skills, the COVID-19 pandemic has exacerbated pre-existing skills shortages (Causa et al., 2022). In light of these changes, it is becoming increasingly important to implement policies that can support the alignment of the skills of workers and individuals with the needs of the labour market. Skills imbalances, such as shortages (when adequate skills are hard to find in the current labour market) or surpluses (when certain skills are in excess in the labour market relative to the demand and therefore easy to find) can impede the uptake of new technologies, cause delays in production, increase labour turnover and diminish overall productivity (OECD, 2022a). Individuals who do not possess the “right” skills also risk facing poor labour market outcomes.

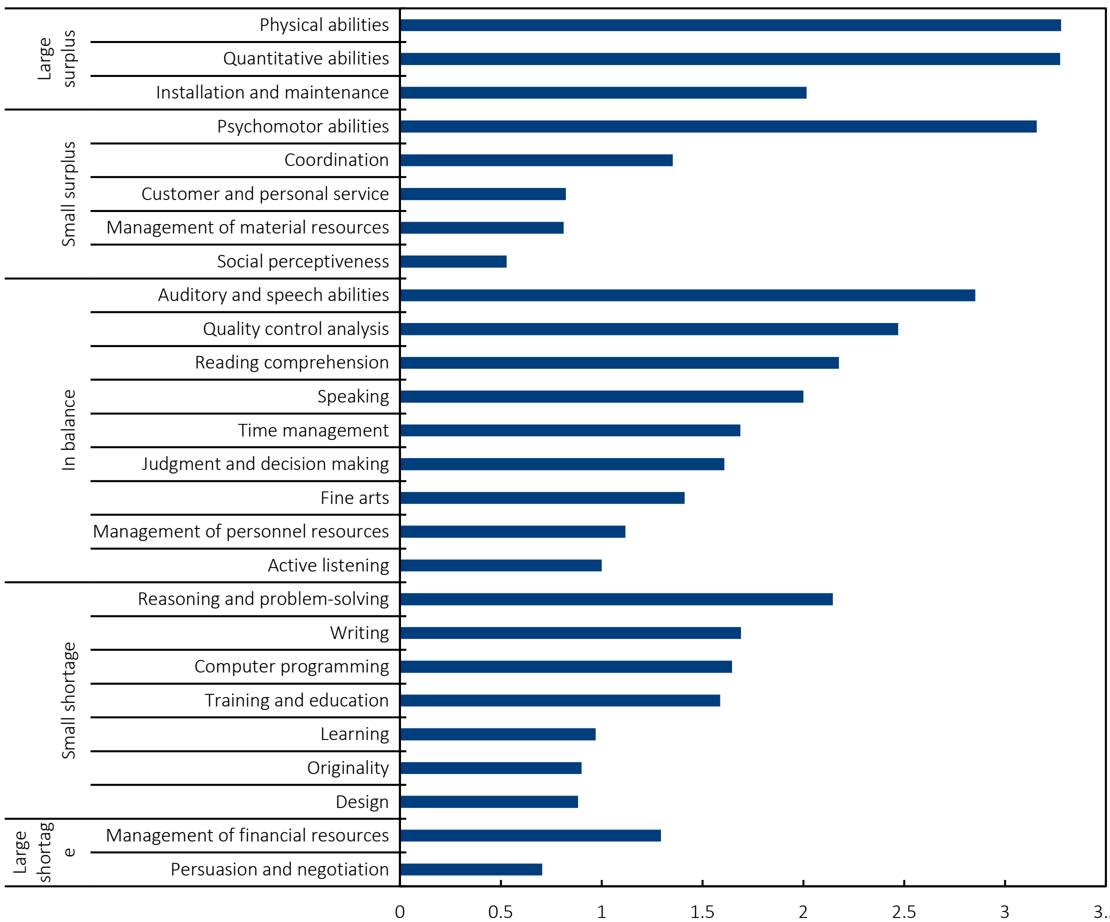
In the transport sector, evidence suggests that automation technologies may exacerbate skill mismatches in some areas but help in others. Figure 13 shows the automation risk by skill, where skills have been grouped according to whether they are in surplus, in balance or in shortage within the transport sector based on the skill supply and demand analysis from the OECD Skills for Jobs database[16].

In many instances, skills in which there are large labour surpluses are also highly automatable. These include physical abilities, quantitative abilities, and installation and maintenance skills. Workers who possess these skills will face challenges in coming decades, experiencing competition not only from other workers with those skills (as evidenced by the current surplus) but also from automation technologies. These workers are likely to be most in need of additional training and upskilling or may experience significant changes in their tasks and even be required to shift sectors[17].

Broadly speaking, the opposite is true for workers who have skills in which there are labour shortages. In addition, these skills are often less automatable. Such skills include management of financial resources, and persuasion and negotiation. Workers who possess these skills are less likely to require intensive upskilling, as their skills are already in demand and are at lower risk of automation. This could lead to greater job security and higher wages.

However, the picture is, in some ways, more nuanced. While the overall automation risk is higher where there are already surpluses and lower where there are shortages, within high-risk and low-risk skills, there is variation in current demand. This may mean that automation can, in certain instances, ameliorate skills shortages and, in other cases, modest surpluses may remain modest with increasing automation. For example, small shortages of certain skills may be relieved by automation, such as in problem-solving, writing, and computer programming. The advent of AI may also result in surpluses in areas such as auditory and speech abilities and quality control analysis.

Figure 13. Automatability measure for skills, grouped according to the level of surplus or shortage



Note: Calculations are based on the OECD Expert Survey on Skills and Abilities Automatability and O*NET. The measure has a scale between 1 and 5 (low indicating low automation risk and vice versa).

Source: Lassébie and Quintini (2022) and OECD Skills for Jobs database.

Jobs are comprised of different tasks, and each task requires a mix of different skills. Given that a range of skills and abilities are called upon to perform a job, the evidence presented in this section suggests that job obsolescence is unlikely for workers in the sector, as the mix of skills is complex. However, changes in the task mix of many jobs are certain and, for some jobs, will be profound. The growing speed of advances in AI technologies highlights the need for continued monitoring of skill needs and mismatches to identify areas where upskilling is required. The analysis suggests that, while there are areas where increasing adoption of AI technologies may exacerbate skills surpluses, in other areas, skills shortages may be ameliorated.

The impact of automation on inclusiveness

An important consideration for policy makers and industry is how to capture the benefits of technological progress (i.e. increased productivity and economic growth) without increasing inequalities and societal resistance to technological progress. Policy makers will want to understand which groups are most likely to be left behind or disadvantaged so to target income support and training, and help at-risk workers transition to new jobs.

This section examines which groups are most likely to be exposed to automation, both in the urban passenger transport sector and in all the sectors. The impact of automation on inclusiveness also concerns the groups best positioned to adapt to new technologies. Even within exposed occupations, skills may act as a buffer to the negative effects of automation. Tenure and job stability may also play an important role for older workers. This section also discusses how technological advances can bring new opportunities for traditionally underrepresented groups – as long as artificial intelligence (AI) systems are designed not to perpetuate existing biases.

Who will be most impacted by automation?

Across the economy as a whole, men and low-educated workers are most exposed to automation. Occupations at high risk of automation are typically male-dominated (Lassébie and Quintini, 2022). This may reflect the fact that women are present in occupations requiring interpersonal skills or other human interactions that cannot yet be performed by automation technologies (see section on bottleneck skills in "Which skills in the urban transport sector are at risk of automation")[18]. Lassébie and Quintini (2022) also show that low-educated workers are more likely than workers with middle or high levels of education to be employed in occupations at high risk of automation and that younger and older workers are more likely to be employed in these occupations than prime-age workers.

The analysis that follows directly considers the exposure to automation of different socio-economic groups working in the occupations most closely associated with the urban passenger transport sector. To represent the demographic composition of this sector more accurately, the analysis uses a narrower definition of the "urban passenger transport sector" to the analysis presented in the section "Effects on employment levels", and a different approach to the original research performed by Lassébie and Quintini (2022), as detailed in Box 3.

Box 3. Methodology underlying the demographic analysis of workers in the urban transport sector

The analysis in this section applies the approach of Lassébie and Quintini (2022) to a set of occupations judged to best represent the demographic composition of the urban passenger transport sector, as determined by ITF using O*NET occupations and presented in the table below[19]. The analysis shows that 14.5% of skills and abilities in this set of occupations are considered highly automatable, compared to 12.6% across all occupations.

Table 5. Set of occupations included in the demographic analysis

SOC three-digit occupational categories	Description	% of highly automatable skills and abilities
41-3	Sales representatives, services	6.3%
49-3	Vehicle and mobile equipment mechanics, installers and repairers	20.0%
53-1	Transport supervisors and material moving workers	8.8%
53-3	Motor vehicle operators	22.2%
53-4	Rail transport workers	18.4%
53-5	Water transport workers	14.9%
53-6	Other transport workers	16.7%

Note: The third column shows the percentage of highly automatable skills and abilities within each occupation, as estimated in Lassébie and Quintini (2022). Nevertheless, none of these occupations is considered at "high risk of automation", as defined within Lassébie and Quintini (2022) as occupations in which 25% or more of skills and abilities are highly automatable. This prevents a direct comparison with the demographic analysis presented in Lassébie and Quintini (2022). Instead, the analysis presented in this section is based on the share of skills and abilities in each occupation considered highly automatable, taking into account the demographic composition and size of that occupation.

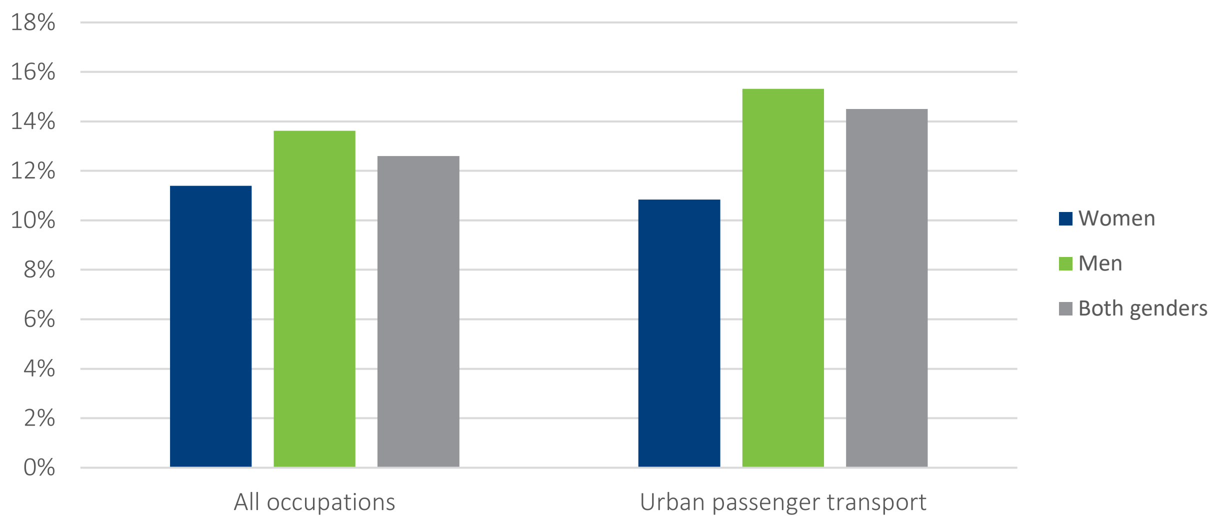
Source: Lassébie and Quintini (2022)

Groups most likely to be exposed to automation

Men are more exposed to automation in the urban passenger transport sector than in the economy as a whole. A non-negligable 15.3% of the skills and abilities used by men[20] within the urban passenger transport sector are considered highly automatable, compared to 10.8% for women (Figure 14). This compares to 13.6% and 11.3%, respectively, across all occupations[21]. This difference is driven by the fact that almost half of all men in the urban passenger transport sector are in occupations in which over 18% of skills and abilities are considered highly automatable: vehicle and mobile equipment mechanics, installers and repairers; rail transport workers; and motor vehicle operators. Women are even more underrepresented in these occupations than they are in the other occupations associated with the urban passenger transport sector.

The results suggest that women's representation in the urban passenger transport sector is unlikely to be further reduced by automation. This mirrors the views expressed in an EU study (European Commission, 2021) in which most stakeholders interviewed did not think that automation and digitalisation would negatively affect female employment in transport.

Figure 14. Automation risk in urban passenger transport versus all sectors, by gender



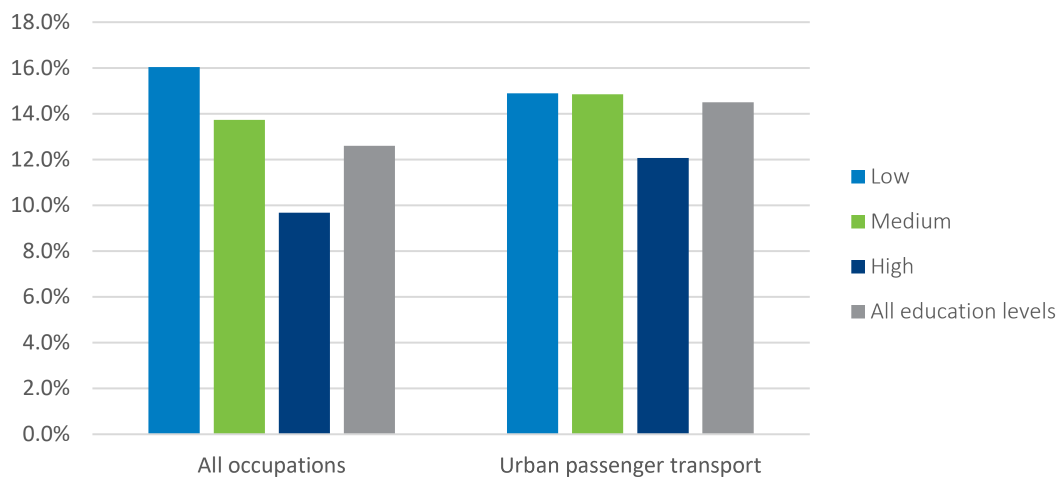
Note: The blue bars represent (share of women in occupation) x (share of highly automatable skills and abilities in occupation), aggregated over all occupations, scaled by women's workforce participation in each country, averaged across countries.

Source: Based on the OECD Expert Survey on Skills and Abilities Automatability (OECD, 2022), as used in Lassébie and Quintini (2022).

While higher-educated workers are less exposed to automation than low-educated workers, the gap between high and low is smaller within the occupations associated with the urban passenger transport sector than it is across all occupations. As Figure 15 shows, 14.9% of the skills and abilities[22] within the urban passenger transport sector are considered highly automatable, compared to 16% across all occupations; 12.1% of the skills and abilities used by high-educated workers are considered highly automatable, compared to 9.7% across all occupations.

The gap is smaller in the urban passenger transport sector as the occupations associated with the highest risk of automation (motor vehicle operators, vehicle and mobile equipment mechanics, and installers and repairers) account for almost an equal share (34-37%) of the low-educated and high-educated urban passenger transport workforce.

Figure 15. Automation risk in urban passenger transport versus all sectors, by education

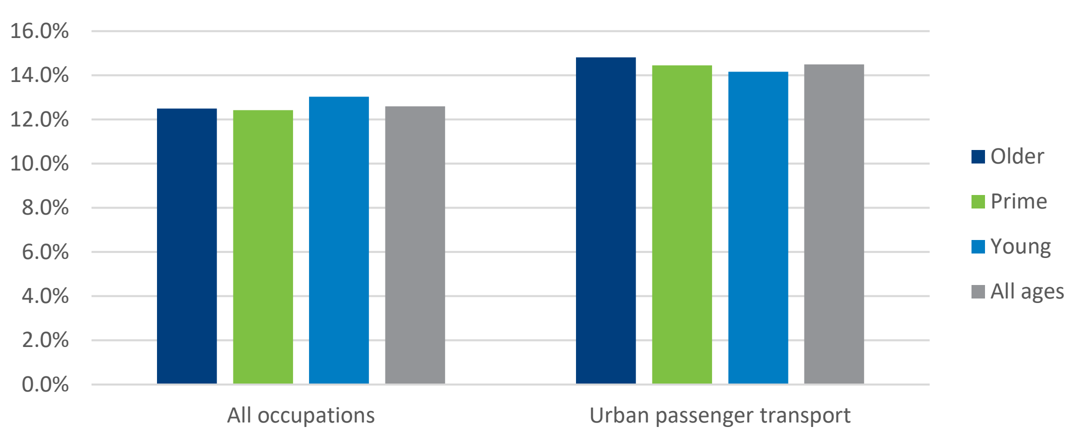


Note: The light blue bars represent (share of low educated in occupation) x (share of highly automatable skills and abilities in occupation), aggregated over all occupations, scaled by low educated workforce participation in each country, averaged across countries.

Source: Based on the OECD Expert Survey on Skills and Abilities Automatability (OECD, 2022), as used in Lassébie and Quintini (2022).

There are few differences in automation risk by age, either in the urban passenger transport sector or in the economy as a whole. Approximately 12-13% of skills and abilities in occupations most closely associated with the urban transport sector are considered highly automatable, compared to 14-15% across all occupations (Figure 16). Young workers (aged 15 to 29) account for 19% of the urban passenger transport sector, while prime-age workers (aged 30 to 54) account for 59% and older workers (aged 55 or above) account for 22%, which is a similar composition to that of the economy as a whole.

Figure 16. Automation risk in urban passenger transport versus all sectors, by age



Note: The dark blue bars represent (share of older workers in occupation) x (share of highly automatable skills and abilities in occupation), aggregated over all occupations, scaled by older worker participation in each country, averaged across countries.

Source: Based on the OECD Expert Survey on Skills and Abilities Automatability (OECD, 2022), as used in Lassébie and Quintini (2022).

Some groups may be more capable or better positioned to adapt to automation

The impact of automation on inclusiveness is not just about which groups are most exposed but also about which groups are most capable of adapting. Recent advances in AI allow the automation of some skills typically associated with high-skilled jobs, such as reading comprehension, deductive and inductive reasoning skills, fluency of ideas and scheduling skills (Lassébie and Quintini, 2022). As mentioned previously, this does not necessarily mean that these jobs will disappear. If workers can successfully adapt to the reorganisation of tasks and the emergence of new tasks, weather potential job loss and navigate transitions to new jobs, they may ultimately benefit.

There is some evidence that more educated and higher-income workers have better employment prospects after exposure to AI. Empirical studies find larger positive wage effects of AI adoption among individuals with higher educational attainment (Fossen and Sorgner, 2019) and in higher-wage occupations (Felten, Raj and Seamans, 2019). Additionally, Acemoglu et al. (2020) find that individuals in lower-wage occupations were more likely to be substituted by AI, while Georgieff and Hyee (2021) find AI exposure increases employment growth only in occupations with the highest degree of computer use, which tends to be associated with higher education and income levels[23]. Fossen and Sorgner (2019) explain that highly educated workers have a greater ability to learn new information and adapt to new technologies and are more likely to possess skills that cannot be easily automated, such as creative and social intelligence, reasoning skills and critical thinking.

Low-skilled workers risk being left behind. Firm-level interviews in the manufacturing and finance sectors of eight OECD countries revealed that the implementation of AI technologies had a disproportionately detrimental impact on low-skilled workers due to their lack of readiness to transition to new tasks and/or jobs (Milanez, 2023). In some cases, all workers interacting with AI were expected to have some understanding of data mechanisms and even limited AI knowledge. Without these skills, firms could perceive the learning gap between current and required skills to be too large, preferring to hire new workers over training existing ones[24,25]. In a survey of employers in the manufacturing and finance sectors of seven OECD countries, low-skilled workers were perceived as one of the groups most likely to be harmed, rather than helped, by AI (Lane, Williams and Broecke, 2023).

The gap between low- and high-skilled workers could be exacerbated if workers in high-skilled occupations have greater access to lifelong learning. Low-skilled adults are 23 percentage points less likely to train than those with medium or higher skills (OECD, 2019a). Other groups that participate less in adult learning include older people, low-wage workers, workers in SMEs and temporary workers. Furthermore, participation in training in the transport industry is lower than in other sectors, at least across the European Union. In 2022, 10.1% of employees in the Statistical Classification of Economic Activities in the European Community (NACE) sector H (transportation and storage) had participated in education and training in the four weeks preceding the interview, compared to 15.7% across all sectors (Eurostat, 2023). Furthermore, research shows a negative relationship between an occupation's exposure to automation and the share of workers undertaking training (Lassébie and Quintini, 2022): workers in high-risk occupations are eight percentage points less likely to respond that they have participated in education and training activities in the four weeks preceding the survey than workers in other occupations. It is concerning that the workers who may need training the most are least likely to access it.

Older workers may also face barriers to adapting to new technologies. In case study interviews carried out in the manufacturing and finance sectors, older workers were often perceived as sceptical towards AI technologies, which interviewees said made them less inclined to adapt to change and engage in training programmes (Milanez, 2023). Whether this scepticism was real or a reflection of ageism in the workplace (OECD, 2020), it could prevent older workers from engaging with new technologies and from training opportunities. Surveys of workers mirrored this perception (Lane, Williams and Broecke, 2023), with employers seeing older workers as one of the groups most likely to be harmed by AI. The idea of age-biased technological change, whereby the adoption of technology disadvantages older workers, is well established (e.g. Behaghel, Caroli and Roger, 2011).

Despite these barriers, older workers' tenure and seniority may afford them certain protections. Fossen and Sorgner (2019) found that the positive wage effects associated with AI adoption were stronger for older, more experienced workers. Survey evidence similarly shows older workers were less worried about job loss[26], which regression analysis attributed largely to the fact that these workers tended to be in more secure working arrangements; specifically, they were less likely to hold temporary or fixed-term contracts (Lane, Williams and Broecke, 2023). In case studies carried out in the manufacturing and finance sectors (Milanez, 2023), some employers described a strong cultural impetus to retain and redeploy workers with long tenures (including until retirement or voluntary separation), even when the AI had reduced the need for labour. As mentioned previously, automation may impede entry to exposed occupations more so than it induces job loss, in which case younger workers will be disproportionally impacted[27].

Some groups may face barriers accessing the opportunities associated with new technologies

It is important to ensure that the opportunities associated with new technologies are open to all. Many ICT and AI-related jobs are comparatively lucrative (Manca, 2023; OECD, 2018). However, women are underrepresented in ICT task-intensive jobs[28]. Additionally, recent OECD analysis (Green and Lamby, 2023) reveals that the "AI workforce", defined as those with the skills to develop and maintain AI systems, is confined to a narrow demographic segment of the population, primarily male and with a tertiary degree. Even among AI users, men and workers with a university degree were most positive about how AI had impacted their productivity and working conditions and most likely to expect AI to lead to wage increases in future (Lane, Williams and Broecke, 2023).

If certain groups face barriers to accessing the opportunities associated with new technologies, this may increase inequality in employment and pay as automation technologies become more prevalent. Furthermore, the underrepresentation of certain groups in ICT and AI-related jobs and in key decision-making roles increases the chance that the experiences and voices of these groups are ignored in the development of new technologies, possibly perpetuating discrimination and inequality (ITF Global, 2021).

How automation can provide opportunities for traditionally underrepresented groups

Despite the challenges that automation poses for inclusiveness, the associated technological advances may bring new opportunities for traditionally underrepresented groups (such as women and younger people, in the case of the urban passenger transport sector) – as long as systems are specifically designed not to perpetuate the biases that already exist.

AI technologies can improve the efficiency and quality of the process of matching job seekers to vacancies, with advantages for underrepresented groups (Broecke, 2023). One consequence is that vacancies are filled more quickly, thus reducing unemployment. Another is that firms are more likely to hire the right jobseeker for the right job, overcoming the challenge of imperfect information as well as bias and discrimination, which may be factors in the exclusion or underrepresentation of certain groups. While there are concerns about AI perpetuating and amplifying biases (see below), some developments have given reason for optimism. AI-enabled hiring algorithms can simultaneously increase the diversity of the talent pool and find the best workers if they strike a balance between selecting from groups with proven track records and selecting from underrepresented groups (Li, Raymond and Bergman, 2021). Another study (Pisanelli, 2022) showed that the use of assessment software increased the share of female managers hired by companies, possibly because they offered a more data-driven and objective approach.

Ride-hailing companies use machine learning algorithms for matching, which provides earning opportunities for individuals who might otherwise face barriers to employment. This matching process is entirely data-driven and automated, learning from past experience to estimate demand at a particular time in a certain location, informing drivers, planning routes, and setting prices (as well as bonuses and incentives) depending on supply and demand. Drivers are not monitored by a supervisor but instead by a rating system which relies on passenger evaluations. While there are concerns about the quality of platform work[29], it is associated with lower entry barriers, which may provide earning opportunities for individuals who might otherwise be excluded from the labour market (e.g. migrants, young workers without experience).

Digital advances may improve access to training for those who would otherwise face barriers. Verhagen (2021) describes how using AI for training has the potential to increase participation, including among currently underrepresented groups, by lowering some existing barriers and increasing motivation to train. For instance, tailored content and assessment may shorten the required time commitment and reduce costs. The use of practice-oriented augmented reality (AR) and virtual reality (VR) may be more engaging for adults who struggle with classroom-based education and written materials and instructions (e.g. non-native speakers or people with low literacy skills). Finally, just as AI can match job seekers to jobs, certain AI solutions for training may improve the alignment of training to labour market needs and to learner entry levels, increasing the relevance of training.

However, these AI applications are not without controversy. The algorithms used by platforms have been accused of lacking transparency (Aranguiz, 2021), invading workers' privacy (Baachi and Asher-Schapiro, 2020) and producing biased decisions (Kerr, 2020). Similarly, there are risks involved with the increased use of AI by human resource departments and employment services. AI can be a black box, and without knowing how recommendations and decisions are arrived at, it is dangerous to take them at face value – especially in the employment sphere where the consequences for individuals can be significant (Broecke, 2023).

One particular concern is that these applications of AI can amplify and systematise existing biases, perpetuate the exclusion of underrepresented groups and reinforce historical patterns of disadvantage (Salvi et al., 2022). This can happen not only intentionally but also because of how the algorithm learns from existing data. For instance, if training data mostly comprises male employees, the algorithm may become very good at predicting the top-performing men and mediocre at figuring out the top-performing women. Even if the hiring company then makes an effort to interview an equal number of these top-performing men and women, a man is still more likely to get the job (Rivero, 2020).

Employers expect AI to help some traditionally underrepresented groups, but to harm others

Employers see workers with disabilities as a group that could particularly benefit from AI in the workplace, while they expected older and low-skilled workers to face more harm (Figure 16)[30]. This could be because employers think that AI can enable workers with disabilities to enter the workforce and can supplement and complement their skills, as discussed in Box 4. Employers see female workers, migrant workers and workers from an ethnic minority as among the least likely to be harmed by AI.

Box 4. Can AI improve access to the labour market for people with disabilities?

People with disabilities continue to struggle in the labour market. In 2019, across 32 OECD countries, they were over twice as likely to be unemployed as people without disabilities. The employment rate of people with disabilities was 27 percentage points lower than for people without. This gap has not declined over the last decade (OECD, 2022b).

AI-powered solutions may help remove some of the barriers to employment faced by people with disabilities[31]. Disability-centred solutions that are directly aimed at addressing individual impairments can facilitate the daily and professional lives of people with disabilities (e.g. speech recognition, live captioning systems, image recognition devices). AI can help make the environment more accessible. For example, conversational chatbots that can read aloud and summarise the content of job offers allow blind and/or neurodivergent users to access traditionally inaccessible job boards. AI-powered accessibility checkers help refine documents and websites to ensure they can be accessed by people with disabilities.

More generally, automation in the urban transport industry and the development of automated vehicles (AVs) could help remove an important barrier to employment for people with disabilities, namely transport (Department of Labor ODEP, 2019). On-demand AVs could provide a cheaper alternative to the expensive paratransit options (i.e. individualised accessible rides without fixed routes or timetables supplementing public transit systems) currently available to people with disabilities for “first and last mile” transport to and from fixed-line transit options (Fiol and Weng, 2022). The absence of steering wheels and dashboards means that AVs could more easily be built to accommodate assistive devices such as wheelchairs than more traditional vehicles[32].

To guarantee accessibility and build user trust, the disability stakeholder community should be closely involved in the development and deployment of AVs. Governments also have a role to play in setting accessibility standards, enforcing clear accessibility requirements in public procurement (Claypool, Bin-Nun and Gerlach, 2017; Department of Labor ODEP, 2019; Fiol and Weng, 2022), creating safe pickup and drop-off curb spaces for AVs, guaranteeing their accessibility beyond the design of the vehicle (Fiol and Weng, 2022), as well as through subsidies to ensure the affordability of public transit AVs in the future (Department of Labor ODEP, 2019; Fiol and Weng, 2022).

Source: Touzet (2023, Forthcoming).

Implications for the urban passenger transport sector

Given that not all workers experience automation equally, automation is expected to change the composition of the labour force in the urban passenger transport sector as well as in other sectors. As established earlier, the transport sector already faces two issues related to the composition of its workforce, with potential consequences for inclusiveness: a gender imbalance and an ageing workforce[33]. Automation could alleviate or perpetuate these issues. On top of this, concerns about the impact of automation on lower and middle-skilled workers are common to all sectors.

Men in the urban passenger transport sector are more exposed to automation, and even more so in occupations related to urban passenger transport, whereas women may struggle to take advantage of new opportunities associated with technological progress. However, exposure to automation does not necessarily translate into job loss. Occupations such as motor vehicle operators (with 22% of skills and abilities highly automatable and is male-dominated) are more likely to transform than to disappear completely. The ultimate impact of automation thus depends on the workers' ability to adapt to changes and to take advantage of new opportunities that arise. This is where women face an acute risk due to the gender gap in digital skills and underrepresentation in ICT and AI-related jobs.

Urban passenger transport workers with low and medium levels of education are more exposed to automation and may struggle to adapt, even if the analysis in this section shows that the gap between these workers and workers with high levels of education is smaller in the urban passenger transport sector than in the other sectors. Furthermore, the empirical evidence suggests that more educated workers have better employment prospects after exposure to AI, possibly because they have a greater ability to learn and adapt and are more likely to possess skills that cannot be easily automated. Additionally, low-skilled workers are less likely to participate in training.

Older and younger workers in the urban passenger transport sector, although facing similar exposure to automation, may face very different challenges. Older workers may need to confront preconceived and even prejudicial notions regarding their ability and willingness to engage with new technologies. On the other hand, older workers' tenure and seniority may afford them certain protections. Previous empirical studies have suggested that lower-tenured, more precarious and lower-paid workers tend to face worse outcomes when exposed to AI. This is an issue, as the transport sector is already characterised by a high degree of informal and precarious work, but this could disproportionally affect younger workers (as well as women). If employers in the urban passenger transport sector halt or slow hiring in entry-level jobs in anticipation or as a result of automation, this will accelerate the ageing of the workforce.

The use of technology in matching and training could provide opportunities for groups currently underrepresented in urban passenger transport if solutions are implemented correctly. However, there are concerns about the quality of the jobs created by matching platforms and concerns that AI-driving matching tools can amplify and systematise existing biases and perpetuate the exclusion of underrepresented groups.

Changes in the nature and quality of work

Job quality provides another opportunity to increase the representation of women and young people within the urban passenger transport sector. The section discusses how automation may help tackle issues such as occupational safety and health, violence and harassment, and work-life balance, which are particularly acute for women and limit women and young people's participation. This section will consider how the nature and quality of work are expected to change as a result of automation and associated advances in digitalisation. Routine physical tasks are expected to be the most impacted within the transport industry, which introduces the possibility of improving occupational safety and health. This section also considers the possible impact on work intensity, worker autonomy, wages and work-life balance.

What tasks can be automated and how will the repartition of tasks between humans and machines evolve?

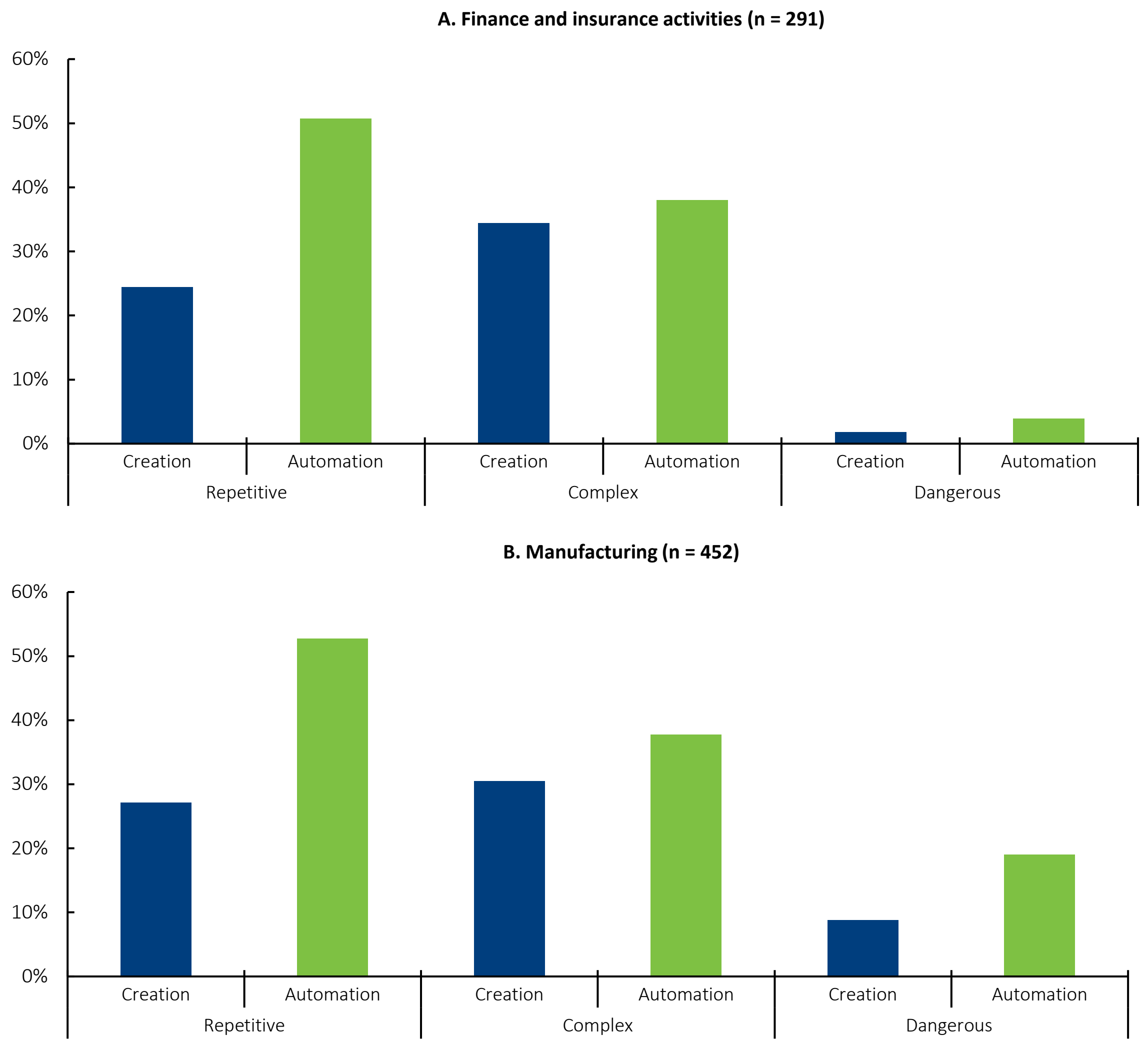
This section considers the nature of the tasks most likely to be automated and created, which has relevance for job quality.

Automation is expected to impact routine physical tasks the most

Technological progress and the emergence of artificial intelligence (AI) means that the scope of automatable tasks can expand over time. While previous automation technologies have primarily automated repetitive or routine tasks (Autor, Levy and Murnane, 2003) and low-skilled tasks (Nedelkoska and Quintini, 2018), AI can automate some complex and non-routine tasks (Aghion, Jones and Jones, 2017; Georgieff and Hyee, 2021) (see Figure 17). For instance, ChatGPT, launched in November 2022, has passed the US Medical Licensing Exam (Delaney, 2023) and has posed as a lawyer for a design firm, recovering more than USD 100 000 in debt (Deccan Herald, 2023). This demonstrates how the bottlenecks to automation are narrowing over time. Nevertheless, complex problem-solving, high-level management and social interaction are still considered bottlenecks, given the current state of technological developments (Lassébie and Quintini, 2022).

However, routine physical tasks may continue to be the most impacted within the transport industry. Stakeholders interviewed as part of an EU study (European Commission, 2021) on automation and digitalisation in transport expected an increase in task complexity and a decrease in manual and physical tasks as occupations become more focused on operating, maintaining, and repairing machines. Mirroring some of the results of the EU study, a report by the World Maritime University (2019) saw the highest potential for automation in predictable physical tasks and tasks related to data processing.

Figure 17. Share of repetitive, complex or dangerous tasks created or automated by artificial intelligence



Note: n corresponds to the number of surveyed workers for each sector.

Source: Lane, Williams and Broecke (2023).

Impact on job quality

The automation of routine physical tasks is naturally expected to improve occupational health and safety. However, there are other developments linked to automation and digitalisation, which could also change job quality within the urban passenger transport sector. For instance, automation can change the interaction between workers and machines and between workers and customers, exposing them to new dangers. The use of AI-enabled tools in the workplace may increase work intensity and stress and reduce autonomy. Where automation boosts worker performance, this may or may not be reflected in pay. Finally, automation and digitalisation could improve work-life balance and address some of the barriers preventing women from participating fully in the urban passenger transport workforce.

Automation can improve occupational health and safety

Automation of dangerous and repetitive tasks would naturally improve occupational health and safety. (Lane, Williams and Broecke, 2023; Milanez, 2023). Automation can also improve occupational health and safety by changing workers' interactions with machines and their exposure to hazardous environments. Autonomous and remotely controlled devices often mean that workers can keep a safe distance from machinery. Examples from the transport industry include remote-controlled cranes and airborne and underwater drones which make it possible to inspect and repair parts of ships and offshore structures (World Maritime University, 2019).

Other technological advances encourage humans and machines to work in close proximity, although risks to physical safety may remain. Exoskeletons can minimise strain and enhance strength when workers perform physically demanding tasks such as lifting heavy objects. Collaborative robotics (cobots) is founded on the idea that AI can enable close co-ordination between humans and robots. However, safety remains a challenge for developers of cobots. Collaborative robotic assembly tasks have been shown to produce mental strain, particularly when the cobot is within two metres of the worker and moves quickly and without warning (Arai, Kato and Fujita, 2010). There are also concerns that if the AI-enabled machines can be operated by workers with less pre-existing training or knowledge than those doing the job before, injuries could result (Moore, 2018).

Another danger in the urban passenger transport sector is violence and harassment, which could be increased or mitigated through automation. These dangers are particularly relevant for customer-facing roles (e.g. ticketing and customer services), in which women are often overrepresented. In theory, automation of these services could provide protection for workers if they can move to roles in which they no longer have to share a physical space with customers[34]. However, a report from ITF Global (2022) highlights a case study from Colombia in which automation of ticketing increased workers' exposure to violence and harassment. When ticket machines broke down and workers were forced to intervene, they experienced more aggression from passengers than before. In addition, a reduced staff presence at stations could place workers at even greater risk of violence or harassment, which could be mitigated somewhat through technologies such as CCTV and emergency response buttons.

Most stakeholders surveyed in an EU study on transport (European Commission, 2021) expected automation and digitalisation to have positive effects on occupational safety and health. Stakeholders noted that the lower reliance on manual and physical work could make the jobs more attractive to underrepresented groups such as women and young people. They mentioned potential improvements to safety standards, to road safety due to automated vehicles, and to service staff on trains due to personal communication devices. Among the stakeholders, those from trade unions and workers' organisations were the most cautious: as many expected occupational safety and health to decrease as expected it to increase.

Artificial intelligence can introduce new sources of work intensity and stress

There is already concern that AI can increase work intensity and stress, particularly when it is used to monitor and assess workers. Firms might be attracted to the idea of a more data-driven and time-efficient approach to people management. However, AI-enabled monitoring and scheduling tools can negatively affect job quality by increasing work intensity and stress (Moore, 2018). If scheduling tools push workers to repeatedly meet specific targets in the interests of efficiency, workers may experience work intensification or reduced autonomy over decision making. In employee surveys on the impact of AI in the workplace (Lane, Williams and Broecke, 2023), three-quarters of AI users in the finance and manufacturing sectors said that AI had increased the pace at which they perform their tasks. The survey did not probe how workers felt about the increased pace, whether this signalled an excessive workload or increased productivity. Another survey of workers in Japan (Yamamoto, 2019) suggests that these dynamics are complex in that AI adoption can contribute simultaneously to greater job satisfaction and increased stress. The authors suggested that AI allowed workers to concentrate on more complex tasks, which intensified work-related stress but possibly also provided a greater sense of satisfaction once accomplished.

AI introduces the possibility of automating decision-making tasks, bringing with it new challenges but also new opportunities for job quality. The more workers are asked to defer to AI in decision making, the less autonomy and fewer learning opportunities they might be expected to retain, which could result in a de-skilling of workers who were previously decision makers. The AI application may also frustrate workers when it produces recommendations that conflict with their own judgement, particularly when they do not understand how the AI came to that recommendation. Box 5 provides an example of where "safety drivers" training autonomous vehicles prefer to retain some autonomy in risky situations. In other cases, workers may find the input into decision making very helpful. Indeed, there is some evidence that when digital systems assist employees with decision making, lower human autonomy could lead to lower "technostress" (Ulfert, Antoni and Ullwart, 2022). In employee surveys on the impact of AI in the workplace (Lane, Williams and Broecke, 2023), over 80% of workers assisted by AI in decision making reported that they liked that AI provided this assistance.

Box 5. Interaction of safety drivers with autonomous vehicles

Interviews with "safety drivers", who sit in autonomous vehicles and are expected to take over if needed, shed light on the experience of drivers interacting with autonomous systems in real-world traffic environments (Chu et al., 2023). Most of the interviewees said that safety driving required much more attention than traditional driving due to the unpredictability associated with combining self-driving hardware, software and external environments. Long periods of concentration left drivers tired by the end of the day.

The interviews suggested that safety drivers preferred to retain some autonomy. Drivers reported disappointment and agitation when the vehicle acted contrary to their intentions. Most expressed a desire to learn more about the underlying operations of the autonomous vehicle, which could help them understand why the vehicle acted as it did. When asked how they would confront a risky situation, most participants said that they would rather take control of the vehicle themselves. This was not necessarily because they believed that the autonomous vehicle would make the wrong decision but because they seemed to prefer to rely on their own judgement in risky situations where their personal safety, liability for accidents, and adherence to traffic laws were on the line.

Source: Chu et al. (2023).

Automation is expected to boost productivity, but it is unclear whether wages will rise in step

Productivity is generally one of the main motivations for businesses to automate, but the impact on wages is unclear. While traditional economic models associate wages with worker productivity, it is an open question whether workers will see productivity gains reflected in higher wages when jobs are being automated. In fact, the last two decades have seen a decoupling of productivity and wages in many OECD countries, with wages growing more slowly than productivity (Schwellnus et al., 2018). Productivity increases will only be shared with workers in the form of higher wages if labour retains its importance within the economy and within the urban passenger transport sector. This relies on new jobs being created for workers to compensate for the jobs lost.

Opinions are mixed on whether automation will increase wages in the transport sector. In one EU study (European Commission, 2021), most stakeholders surveyed (including employers and employers' organisations, national public bodies and research institutes) expected wages to increase as a result of automation and digitalisation. However, stakeholders from trade unions and workers' organisations did not agree. Most expected either a decrease in wages (42%) or no change at all (33%). In an OECD survey of workers in manufacturing and finance (Lane, Williams and Broecke, 2023), twice as many workers expected AI to decrease wages as to increase them. This was striking given that workers were generally positive about the impact of AI on their performance and suggests that respondents did not expect to see productivity improvements reflected in wages.

Automation and digitalisation may improve work-life balance and attract women to the transport sector

Automation and digitalisation could improve work-life balance within the transport sector by providing opportunities for part-time or more flexible working hours and for remote work (European Commission, 2021). These improvements may be particularly valuable for those with family and primary carer duties, and may be attractive to groups currently underrepresented, such as women. Working conditions such as working hours and places of work are barriers to female employment within the transport workforce (Turnbull, 2013). Turnbull provides the example of the road transport sector, which is especially unattractive to women due to working hours, working away from home, and the general lack of family-oriented practices and measures. One OECD paper (Fluchtmann and Patrini, 2023) describes how video-conferencing and teleworking software can make family and work responsibilities more compatible, which can be particularly beneficial for women. The authors note that, since the onset of the COVID-19 pandemic, the number of persons usually working from home has increased at a higher rate for women than for men, while women are more often in jobs that could theoretically be done remotely.

Flexibility can improve working conditions and address some issues of underrepresentation, but only as long as flexibility truly serves the needs of the workers. If flexibility only services the needs of the business and its customers, it then risks undermining job quality. As one EU study (European Commission, 2021) puts it, if flexibility means that working hours are spread out over a 24-hour period, this can blur the boundaries between working time and private life. For example, another study (Eurofound, 2020) shows that telework and ICT-based mobile work are associated with longer working hours, stress and other psychosocial and physical problems. While new forms of work facilitated by digitalisation and AI (i.e. the platform economy) provide flexibility, it is debatable whether this flexibility works in the interests of workers. Some workers are attracted to platform work by the offer of flexibility: flexibility was the most cited motivation for engaging in platform work in the EU Collaborative Economy and Employment (COLLEEM) survey (Pesole et al., 2018). However, even if rideshare drivers, for example, can, in principle, choose their own hours, they are subject to customer demand, which is concentrated in certain parts of the day. They cannot set their own pay rate nor develop their own roster of clients. The consequence is that some platform work is less flexible than it first appears.

Governing transport automation: A way forward

Automation is the answer. But what was the question? Understanding the direction of automation is crucial. Like other technological progress, it is not predetermined. Societies should collectively ask if they should seek to automate tasks or not. Even if some progress may be disruptive, technology is far from being beyond society's control. Public authorities have an active role in steering the direction of automation technologies within the urban passenger transport sector.

Governing automation is challenging for several reasons. On the one hand, automation carries uncertainties inherent to emerging technologies. On the other hand, automation may only be desirable in some contexts or for specific tasks. Based on economic considerations and socio-cultural norms, public authorities and social partners may be more willing to see certain tasks automated (e.g. dispatching, maintenance) than others (e.g. driving, passenger support).

The approach to automation governance should rely on two main pillars. Public authorities should:

- ensure the workforce's ability to transition to a more automated labour market (i.e. adopting automation)
- steer automation with the aim of achieving specific outcomes for societies (i.e. adapting automation).

Adapting to automation: Preparing the workforce for automation

Automation is transforming how tasks are allocated between machines and humans. Some tasks may become progressively more at risk of automation, forcing workers to acquire new skills. As a result, some jobs could become at greater risk of automation, while others may be characterised by bottleneck tasks that require human input (e.g. automation auditing, monitoring automated systems, and safety drivers).

Public authorities must implement strategies to facilitate the adoption of automation by the urban transport workforce. The approach to skills development will need to be adapted to an automated society. The following sections provide actions to adapt the curricula and workforce training.

Building an automation-proof education model

Education is central to building skills for the future workforce (National Academies, 2017; WEF, 2016). The rise of automation is driving the competition between technology and education. Inadequate education systems may prevent the future workforce from benefiting from the substantial benefits associated with a good education. Brynjolfsson, Liu and Westerman (2022b) note that while teaching methods focused on strict adherence to instructions and memorisation have been effective in training workers for routine tasks, these approaches are no longer relevant in the current era, even less in an automated labour market, and could hinder students' capacity to develop the tools needed to access labour markets.

OECD (2023b) highlights the policy implications of evolving artificial intelligence (AI) capabilities for education:

- Education could attempt to increase the skill level of the workforce beyond that of computers. Greater literacy and numeracy would enable workers to understand, interpret and critically evaluate complex texts and mathematical information. Such skills are not only relevant for outperforming AI but also for building the foundation for developing other higher-order skills, such as analytic reasoning and learning-to-learn skills.
- Education could also build upon foundation skills that prove hard for AI. Literacy and numeracy are complex constructs and not always easy for AI. AI still struggles, for example, with language tasks that require logical reasoning and common knowledge.
- Education should strengthen individuals' digital skills. Digital skills would help them to meet the demands of increasingly digitised workplaces and seize the opportunities brought about by technological advances.
- Finally, education should aim at equipping people with well-rounded skill sets. Workers who can better adapt to the changes new technologies induce in their occupations will be more sheltered from automation. Well-rounded skill sets will also ease mobility between occupations since diverse skills apply in different work contexts.

The education system should undergo a transformation to align with the demands of the automation paradigm. Education plays a pivotal role in anticipating the future skills supply and mitigating potential negative impacts caused by technological change. Automation is affecting the demand for skills. Demand for skills in future could be oriented towards competencies that allow workers to adjust to the increasingly complex nature of the transport market. Such evolving needs and unpredictable futures call for transforming the education system. Modern curricula could prioritise developing persistence for non-routine tasks (Brynjolfsson, Liu and Westerman, 2022b).

Furthermore, the unpredictable nature of automation calls for a lifelong and more flexible system. While many urban passenger transport workers could adapt to technological change, others are nearing retirement and may not benefit from such education reform. For example, it would be challenging for bus drivers over the age of 50 to return to school to learn a completely new job. For such groups of workers, public authorities and companies should provide them with solutions to ease re-training and facilitate the transition to a new and less automatable occupation (ITF Global, 2022).

The capacity for workers to navigate the rapidly evolving labour market will depend on their skills (OECD, 2021). A worker's ability to adapt will also rely on their capacity and willingness to acquire skills and learn. Skills acquisition is not limited to education. According to the OECD (2021), lifelong learning includes "all forms of skill development and knowledge acquisition occurring over the lifecycle". In this context, if skills acquired through primary and secondary education and college are critical, skills acquired later in life are equally important to consider, significantly facilitating workforce retraining and upskilling.

Empowering the workforce with new skills

Automation will require an acceleration of adult learning in the transport sector. This has two main objectives. Firstly, it enables the adaptation of the workforce to automation and allows employees to acquire less automatable skills. Secondly, it addresses the need for new skills. The Michigan Mobility Institute notes that sector-wide needs in transport could reach 45 000 new mobility engineers (Michigan Mobility Institute, 2021). This accelerated approach to retraining will enable the transition of the transport labour market and its realignment with future needs (OECD, 2021; WEF, 2018). Looking at cross-industry trends for AI needs, the UITP (2019b) lists the types of skills that will be in high demand for public transport, namely technical skills in IT and data analysis, emotional intelligence, creativity, and managerial competencies. Additionally, in highly automated environments, such as automated vehicle-based services, human-related skills (e.g. emotional intelligence, care qualities, etc.) will be a distinguishing factor for delivering customer service excellence. Similarly, automated systems may need to be paired with individuals with creative skills. Employees with creativity and initiative skills will drive innovation and enable companies to navigate uncertain situations.

Skill development faces many barriers. Firstly, most companies lack the resources to invest in adult learning (Casey, 2020). This is particularly true for small companies. Due to the relatively high upfront cost of training programmes, smaller-scale companies may choose not to invest in human capital development. Additionally, the Michigan Mobility Institute (2019) notes that talent development schemes are often missing. Secondly, employers may be unwilling to invest in their workforce development as they may risk losing their investment if the employees leave. Skills development may even encourage reskilled or upskilled employees to seek better opportunities with other employers (Cavaglia, McNally and Ruiz-Valenzuela, 2021). Thirdly, access to skill development is uneven. When upskilling relies on workers' own resources, employees with lower incomes may lack the financial means to pursue training. In the context of budgetary restrictions, public authorities should incentivise the involvement of employers and individuals in adult learning funding. Financial incentive schemes should have a co-funding element to engage employers and individuals in contributing to the financial burden of adult learning costs. The OECD (2019a) notes that an increasing number of countries are relying on adult learning co-funding with the help of external funding sources. For example, the European Commission's European Social Fund provides grants to co-fund adult learning. Financial incentives should be targeted towards employers and individuals most in need.

Public authorities have a crucial role to play in removing workforce development barriers. They can provide a wide range of financial incentives for employers within the transport sector and individuals to promote the development of new skills (Parr, 2022). Public authorities could incentivise companies to invest in workforce training (IFR, 2018). In many OECD countries, employers can benefit from tax deductions for corporate investment in training (Torres, 2012). Tax incentives allow companies to directly deduct training costs, which provides an advantage compared to investments in other depreciable assets (e.g. robotics, software). Austria implemented a full tax allowance for training investments (Costa et al., 2018; Torres, 2012). This tax is further complemented by a 20% deduction of the expenses from taxable income. This type of subsidy helps mitigate companies' risks when investing in human capital and favours investment in human capital rather than research and development.

Public authorities could incentivise employees to acquire new skills by reducing training costs. Several OECD countries allow individuals to claim tax allowances on training expenses. This may be conditional to several requirements (e.g. skills improvement, change in occupation). The rationale for this type of lever is to overcome the financial limits individuals face when investing in their training (Costa et al., 2018; Torres, 2012). Additionally, public authorities can also support displaced workers in their transition to new jobs by hiring or implementing activation strategies (i.e. conditional unemployment support aimed to bring displaced workers and inactive individuals into the labour market). Such strategies include mutual obligations where unemployed individuals are expected to engage in active job search, attend job interviews, or accept an offer of suitable work in exchange for benefit payments and employment services (Tergeist and Grubb, 2006).

Collaboration with companies and organisations providing upskilling and reskilling programmes will be crucial (ILO, 2016). As part of its Transport Data Strategy, UK DfT (2023) notes that technical skills to manage data are usually located in larger companies, universities and centres of excellence. The inconsistency in data literacy within the transport workforce is a barrier to developing a data-driven culture in the transport sector. To address this challenge, several universities propose upskilling programmes targeting industry partners. In the United States, the Michigan Mobility Institute's MobilityReady initiative aims to accelerate workforce training by connecting universities and companies. This initiative is part of the Mobility On-Ramp Collaboration (MOC), which aims to develop new credentials for transport workers. Several companies (e.g. Bosch, Ford) have partnered with the initiative to address talent needs in Michigan.

Adapting automation: Governing technology for positive impacts

From a labour perspective, automation presents opportunities, risks, and challenges that must be addressed to unlock positive outcomes. According to the OECD (2023a), "good technology governance can encourage the best from technology and can help prevent social, economic, and political harms". Within this context, technology governance refers to the capacity of governments to exercise administrative, economic and political power to steer the development and operation of technology within societies (OECD, 2023b).

The direction of technological change towards more automation is steered by a broad set of developments led by research activities and leading companies (Acemoglu, 2021). But is the technological change in the urban passenger transport sector going in the right direction? Existing trends and progress in terms of research provide input on what can or could be automated. The direction may or may not be optimal. Korinek and Stiglitz (2021) note the possibility of a suboptimal equilibrium when the market steers technological progress alone. Automation can have varied applications. On the one hand, it can empower machines and software to handle repetitive tasks. Still, on the other hand, it can also increase the possibility of monitoring working activities that the employees may not welcome. Public authorities may want to prevent counterproductive impacts of using automated systems on workers.

Governments should anticipate potential changes to adapt automation in the transport sector so that it unlocks positive impacts for societies. Public authorities should consider implementing national policies but also seek international co-operation to harmonise approaches among countries.

Anticipation and an adapted governance framework

Public authorities play a crucial role in governing technology and future changes. However, automation requires a distinct approach to governance that takes the peculiarities of this technological change into consideration. Automation governance will be a challenging decision-making situation. Governments may face a Collingridge Dilemma – or control dilemma where early actions to regulate automation may be effective but may excessively stifle innovation; conversely, policy actions carried out after the consequences of automation have been observed may be ineffective and costly (Genus and Stirling, 2018; OECD, 2023b).

Building an anticipatory approach to automation will guide how emerging technologies are governed. It ensures that the development of automation is directed towards addressing key societal goals. To that end, the governance of automation should shift towards taking policy action at an early stage. Instead of focusing exclusively on governing the impacts and risks of automation, this approach focuses on creating tailored automation governance by engaging with all relevant stakeholders involved in its development.

Societies should define the role of labour in an automated labour market. Transport social partners and collective bargaining have a central role in dealing with an uncertain future of work in the transport sector (OECD, 2019b). Available data in 2021 in the United States shows the transport sector has the highest union membership rate within the private sector (17.6%) (US Bureau of Labor Statistics, 2021). The rail and taxi unions are historically more unionised within the urban passenger transport sector. Transport unions can help public authorities and companies understand the potential labour issues caused by automation. They can suggest adaptations in terms of wages, working time, organisation, and tasks performed. Social partners also work to anticipate potential changes in skills needs in the transport sector. Unions and organisations (e.g. European Transport Workers' Federation, International Transport Workers' Federation, International Road Union, etc.) can undertake and disseminate research work informing public authorities, companies and workers on potential labour changes that automation could cause (ETF, 2022; ITF, 2017; OECD, 2019b; World Maritime University, 2019).

An adapted automation governance framework will guide governments in establishing policies both nationally and internationally. The OECD (2023b) presents a framework that includes a set of anticipatory governance mechanisms based on the common values shared by society (e.g. human rights, security, sustainability, etc.). Promoting values, or a value-based approach to automation, aims to embody these values in technology (Flanagan, Howe and Nissenbaum, 2008). The second aspect of this framework is targeted towards the alignment of automation with user and society needs. Stakeholders' engagement is crucial in this phase. Finally, governments should implement tools to facilitate the governance of automation in practice. The OECD (2023b) notes that governments should start to carry out forward-looking analysis to anticipate the impacts of emerging technology, engage with stakeholders and develop soft law mechanisms to facilitate the adaptation of technology.

Domestic policies to mitigate adverse impacts of automation workers

Public authorities can use a variety of mechanisms to steer technology towards positive outcomes. As in other sectors, they can implement domestic policies to mitigate the potentially adverse effects of automation on workers.

An adapted regulatory framework could help create an environment where positive outcomes are shared. Ensuring that regulation is effective requires a comprehensive understanding of the relevant market dynamics regarding automation and assessing any significant adverse effects or equity issues that must be addressed (ITF/OECD, 2020). These tools can take many forms. National or local authorities can implement nudges, policies, and taxation measures to steer automation in a desirable direction (Korinek and Stiglitz, 2021). In developing countries, public authorities should ensure the alignment of these technologies with local contexts by steering the adoption of automated technologies (Korinek, Schindler and Stiglitz, 2021).

Public authorities will need to find ways to compensate for the potential increase in government spending (e.g. unemployment insurance) and the decline in income tax revenues caused by automation (Abbott and Bogenschneider, 2017; Kovacev, 2020; Mitha, 2017). However, public authorities must also keep in mind the potential negative impacts of a "robot tax" on automation, especially on innovation, competitiveness and productivity (ENO Center for Transportation, 2017; Whitton, 2018).

Harmonise policies for better outcomes for workers

Several intergovernmental bodies are working on defining a framework for the automation of the urban passenger transport sector. For example, the United Nations Economic Commission for Europe (UNECE) hosts the World Forum for Harmonization of Vehicle Regulation[35]. It serves as an intergovernmental body to establish global technical specifications and requirements for automated vehicles (UNECE, 2019). It enables a policy dialogue between countries and develops regulations and norms. It deals with safety, cyber-security, testing and validation methods, and integrating automated vehicles into road traffic. To date, the UNECE has mainly looked at the impacts of automation on labour from a freight and logistics perspective. In 2022, the workshop participants recommended steering the technological developments of automation in a direction that unlocks benefits for societies. Furthermore, they recommend that automation should go hand-in-hand with retraining workers (e.g. retraining, upskilling, reskilling).

Public authorities can also harmonise global policies to steer automation and indirectly act on potentially negative outcomes of automated transport services. Such a global governance strategy could comprise several components, including data governance frameworks (Korinek, Schindler and Stiglitz, 2021).

International agreements on data governance frameworks (e.g. GDPR, Data Act, etc.) introduce rules regarding the fuel of AI systems: data. These frameworks could be expanded to include new rules ensuring that the benefits of automated systems are shared and their harms mitigated (e.g. safety, inclusiveness, accessibility). Data governance frameworks can give users more control over their data or set new transparency rules over the operation of algorithms. They usually go hand in hand with global competition policies to prevent the emergence of data monopolies. Additionally, countries can work on reinforcing the international tax regime to tax transport tech giants adequately. Finally, governments could reform existing intellectual property protection systems to ensure innovators are adequately protected without preventing access to new technologies and associated services.

Notes

1 Gig economy refers to work characterised by short-term contracts and freelance work. For example, in the transport sector, drivers in the app-based ridesharing and delivery industry are considered gig workers."

2 As the worker survey did not ask about job creation, the research cannot say which effect (job loss or job creation) dominates.

3 When firms were recruited to participate in the study, the choice of use case was left to their discretion. Thus, there is a possibility that the case studies selected were AI use cases with more positive impacts on workers than is representative. This could lead to an underestimate of actual job losses.

4 An automatability score (the simple average across experts) was assigned to each skill or ability. Next, the authors calculated the degree of automatability for each occupation by summing the automatability scores of the set of skills and abilities that make up an occupation (with each automatability score weighted by the importance of that skill or ability in the occupation). Refer to Lassébie and Quintini (2022) for more detail.

5 The 25 countries are Austria, Belgium, Croatia, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

6 The Standard Occupational Classification (SOC) system, two-digit SOC describes major groups (e.g. healthcare support, legal, etc.) ; SOC three-digit describes minor groups of occupations that fall within the two-digit SOC groups (e.g. healthcare technologists and technicians, lawyers, etc.).

7 These categories come from the Standard Occupational Classification (SOC) created by the US Bureau of Labor Statistics. The category level here is the SOC two-digit level, which divides all occupations into 22 major groups of occupational profiles.

8 Bottleneck skills are defined as those for which the experts surveyed indicated, on average, low automatability. These include active listening, assisting and caring for others, service orientation and social perceptiveness.

9 Urban transport workers are also contained in the SOC two-digit category “construction and extraction occupations” (e.g. highway maintenance workers), which is also at high risk of automation (2.61).

10 This calculation can be performed for 27 OECD countries, which is the set of countries for which labour force survey data is available at a sufficiently disaggregated level, as explained in Lassébie and Quintini (2022).

11 These projections aim to reflect expected structural changes within the economy (i.e. economic growth and changes in its sectoral composition) as well as in occupational and skill structure due to factors such as digitisation and automation. More information is available at: https://www.cedefop.europa.eu/en/tools/skills-forecast.

12 Note that “risk of automation” is used as shorthand to refer to the susceptibility of skills and abilities to redundancy by automation technologies. However, it is tasks rather than skills that are automated.

13 Another approach to assess the automatability of job tasks is to take measures of advances in automation technologies or AI and link them to skills and abilities (e.g. Felten, Raj and Seamans [2017, 2019] and Webb [2020]). For an overview of this evidence, see Lassébie and Quintini (2022).

14 Urban transport jobs are also contained within the occupation categories “construction and extraction” and “installation, maintenance and repair.” These categories also have relatively large shares of highly automatable skills and relatively low shares of bottleneck skills.

15 Note that the set of skills that are important is not a comprehensive list of skills required in the sector. Borrowing from Lassébie and Quintini (2022), a skill is regarded as important to an occupation if its importance measure from O*NET is greater than or equal to three. For the full set of skills required by occupations in the sector, see Lassébie and Quintini (2022).

16 The OECD Skills for Jobs database is an analytical tool designed for policy makers, practitioners and the general public to understand where gaps are emerging between skill supply and demand, by providing country-level information for a wide range of skill categories, including cognitive, social and physical skills.

17 Physical skills are likely to be in demand elsewhere in the labour market, e.g. as personal care and service workers.

18 These results are consistent with other findings in the literature, reporting that women have been less exposed than men to previous and current waves of automation (Webb, 2020).

19 Demographic analysis of EU-LFS data is possible at the three-digit SOC level but not at the 6-digit level, the latter offering more precision in the isolation of urban passenger transport occupations. The selection of three-digit SOC occupations attempts to strike a balance between the information shown in the sunburst chart (Figure 3) with consideration of how to best reflect the demographic characteristics of the urban passenger transport sector. As the demographic composition of each occupation varies considerably, results are expected to be sensitive to the chosen set of occupations.

20 The figures are scaled to take into account the gender composition of the workforce, i.e. the fact that women account for 19% of the workforce within the urban passenger transport sector compared to 47% of the overall workforce.

21 The analysis presented in the section "How automation changes skill needs" on the share of skills considered highly automatable in the transport sector relied on a different set of occupations. Nevertheless, the findings are the same: on average, transport occupations are characterised by higher shares of highly automatable skills compared to all occupations.

22 The analysis takes into account the composition of the workforce, i.e. the fact that low-educated workers (those who have not completed upper secondary education) account for 23% of the workforce within the urban passenger transport sector, compared to 15% of the overall workforce. High-educated workers (those who completed tertiary education) account for 17% of the workforce within the urban passenger transport sector, compared to 25% of the overall workforce.

23 Georgieff and Hyee (2021) also find a reduction in working hours in occupations with the lowest degree of computer use. Fossen and Sorgner (2019) also show that the link between AI exposure and employment stability (lower odds of transition into non-employment) is strongest for more educated workers. Felten, Raj and Seamans (2019) find a positive relationship between employment growth and AI exposure for high-skill (high income) occupations but not for low- and medium-skill occupations.

24 Conversely, firms may be more willing to retain and retrain workers with specialised skills who they think would be more difficult to replace.

25 In some cases, interviewees mentioned that deskilling opened up opportunities for unskilled workers, such as workers with elementary English skills. However, as deskilling represents a decrease in the need for labour, it would be expected to put downward pressure on wages, employment and working conditions overall.

26 For instance, 17% of workers aged 50 or over said that they were very or extremely worried about losing their jobs in the next 10 years, compared to 26% of workers aged 18 to 24.

27 OECD analysis (OECD, 2020) has shown that the decline in the share of middle-skill employment (i.e. polarisation) is due primarily to fewer younger workers entering middle-skill occupations than to mid-career workers being displaced and leaving them. Since the 1990s, successive cohorts of young workers have been increasingly less likely to enter the labour market in middle-skill jobs – e.g. truck drivers and machine operators for men, cashiers and secretaries for women. Meanwhile, labour market trajectories of older cohorts after labour market entry have remained essentially unchanged.

28 There are concerns that the gender gap in digital skills could hold women back from the opportunities. For example, women aged 16-24 are less than half as likely to be able to programme as men of the same age (OECD, 2022b). Such gender gaps in digital skills emerge early and result from choices made well before entering the labour market. As girls and women are less likely to enrol in science, technology, engineering, and mathematics (STEM), and are particularly underrepresented among new entrants in ICT educational fields, they risk lagging behind in digital literacy and skills throughout their working lives (UNESCO, 2019; UNESCO/OECD/IDB, 2022).

29 In terms of income instability, compromised access to social protection, limited career development and inadequate rights to collective bargaining (Lane, 2020).

30 The survey was limited to employers in the manufacturing and financial sectors only and did not include employers in the transport sector. However, since these opinions were common to both of these sectors, selected for the study for their heterogeneity, it seems plausible that similar opinions could be common to the transport sector also.

31 Claypool, Bin-Nun and Gerlach (2017) estimate that removing transport-related barriers to employment for people with disabilities would allow approximately 2 million individuals with disabilities to access jobs in the United States. Reports frequently cite commuting difficulties as one of the most important barriers to employment for people with disabilities (National Council on Disability, 2015). Although this barrier might have become less important since COVID-19 and the expansion of telework, it is likely to remain a substantial barrier in the age of mostly hybrid (rather than fully remote) work.

32 On the other hand, automated vehicles will likely be electric, which typically means a higher floor and less space for wheelchairs, due to the placement of the battery.

33 Women are underrepresented in the transport sector generally and overrepresented in less senior, lower paid and more precarious jobs, while an ageing workforce combined with difficulties attracting young drivers raise the risk of driver shortages.

34 Of course, automation could also mean job loss.

35 UNECE's World Forum for Harmonization of Vehicle Regulations (WP.29), https://unece.org/transport/vehicle-regulations/world-forum-harmonization-vehicle-regulations-wp29.

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Published: 09/2023 | Photo montage: AUUSanAKUL and shaineast/Shutterstock