International Transport Forum

The Innovative Mobility Landscape

The Case of Mobility as a Service

Case-Specific Policy Analysis

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The International Transport Forum

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Foreword

Mobility as a Service (MaaS) challenges various existing models in organising and delivering mobility within and outside urban areas. MaaS presents opportunities for new value creation as well as market creation, and has attracted the attention of established and new market actors. The concepts underpinning MaaS – user-centricity, seamless digital experience, bundled services and integrated payment and information management – have the potential to address persistent and growing mobility challenges across different contexts and world regions. Public authorities hope to harness MaaS to better achieve public policy objectives designed to tackle those challenges.

Despite potential benefits, MaaS remains largely untested at scale, and consequently, there is little available evidence regarding its impacts, either positive or negative. Further, a viable and remunerative business model for MaaS – as well as many of its component parts – is unclear and fraught with structural tensions that may only partially be addressed through regulation.

Much has been written about MaaS – from multiple and sometimes conflicting perspectives. The objective of this report is not to revisit this rich discussion, but rather to take stock of the current understanding of MaaS and how it may be usefully implemented to produce a vibrant mobility service ecosystem that delivers clear benefits to people and is aligned with societal objectives.

This report first addresses the current and future context for urban mobility including the sustainability challenges ahead. It reviews how the urban mobility landscape is changing with respect to mobility operators and services. It then addresses the development and characterisation of Mobility as a Service as a means to improve urban mobility outcomes. Finally, it reviews a number of essential governance and regulatory challenges that must be addressed to create a healthy mobility as a service ecosystem that delivers clear benefits to people and is aligned with societal objectives.

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Table of contents

Figures

Tables

Boxes

Executive summary

What we did

This report presents the results of a project carried out jointly by the ITF and the World Business Council for Sustainable Development (WBCSD). It begins by addressing the current and future context for urban mobility, including the sustainability challenges ahead. It then reviews how the urban mobility landscape is changing with respect to mobility operators and services. Next, it addresses the development and characterisation of Mobility as a Service (MaaS) as a means to improve urban mobility outcomes. Finally, it reviews a number of critical governance and regulatory challenges that stakeholders must address to create a healthy Mobility as a Service ecosystem that delivers clear benefits to people and is aligned with societal objectives.

What we found

More people travel further and faster than at any other time in history. This mobility has fuelled economic and social gains around the world. However, it has come at a cost, compromising safety, health, equity, efficiency and posing both local and global environmental threats – most fundamentally, for global climate change. On top of these tensions, the Covid-19 pandemic has caused immense disruption to urban mobility, underscoring the need for greater resilience. Going forward, a growing world population combined with fast-paced urbanisation will increase transport demand in cities. Public transport, active and shared mobility, and Mobility as a Service are all essential to mitigate the impacts of that demand.

A one-size-fits-all approach to addressing benefits and challenges of urban mobility cannot work -- a new approach to mobility encompassing, but moving beyond sole dependence on, the car is necessary. The mobility landscape is evolving rapidly, with new layers, more choices and more digital components. Regulating new mobility services requires an understanding of the external impacts these impose, since shared mobility is not necessarily green mobility and its ultimate effect on sustainability will partly depend on whether these substitute for or complement other services.

Mobility as a Service promises significant benefits from integrating mobility offers. It should be seen as a distribution model for mobility, not as an app nor as a travel mode. MaaS may enable new value creation in low-margin urban mobility markets and thus allow MaaS operators to achieve remunerative margins leveraging new or multiple revenue streams. However, evolving MaaS business models necessarily involve interactions among settled and emerging service delivery models; longer-term market dynamics and the regulatory frameworks that will be needed are far from clear.

For MaaS to grow, people must choose it over other travel options, and this will not be a simple matter. Evidence suggests that MaaS may not prove a compelling substitute to car ownership for a broad segment of the population at the outset. Further, MaaS cannot deliver on the public policy aspirations it inspires without a supportive environment and high-quality public transport system.

The regulation of MaaS ecosystems comprises the regulation of mobility services/operators and the regulation of digital platforms and MaaS aggregators. A well-functioning market will also require a supportive policy framework and flanking measures (e.g. addressing data regulation, pricing, urban access management and adapted multi-modal infrastructure). What the regulatory framework will eventually look like will differ across countries and urban contexts. Nonetheless, the regulation should be guided by principles that are tested and well understood in other, analogous markets. One thing is clear: there are aspects of the digital economy that mobility regulation has yet to address effectively.

What we recommend

Anchor the governance of Mobility as a Service in a strategic vision, applied to the whole functional urban area and informed by effective digital monitoring

MaaS should be integrated into a broader vision addressing public welfare, transport and urban development outcomes. This vision would help define the strategic outcomes to which MaaS contributes. Sustainable Urban Mobility Plans in Europe and the comprehensive MaaS pilot assessment process in Japan are examples of the vision required. This strategic vision should extend to the effective urban mobility catchment area, which may require adjusting institutional responsibilities across administrative boundaries. Finally, MaaS governance should be informed by a comprehensive mobility-monitoring framework that not only includes but extends beyond digitally-enabled mobility services.

Seek greater understanding of how Mobility as a Service can add value for the user

Market configurations allowing MaaS to deliver value to users though commercially viable business cases are still elusive. The "mobility budgets" that companies are required to offer employees in Belgium and tourist market MaaS arrangements in Japan are examples. "Services as a Service" type models have also appeared, incorporating the MaaS offer into wider lifestyle services focused on shopping and banking. These user-focused models could serve as a starting point for better understanding what constitutes viable mass-scale MaaS models how they create value for users.

Guide Mobility as a Service where necessary to achieve agreed societal outcomes

Public authorities should monitor and retain oversight of the MaaS ecosystem and guide it, if necessary, to deliver on public policy objectives. This may involve public authorities adapting their governance practices to address specific risks that emerge in digital markets. In an environment where MaaS becomes the main interface to access mobility, public authorities will need options allowing them to ensure that societal outcomes are met. This will include for example ensuring that MaaS platforms are operated fairly and adapted data governance rules are implemented.

Adopt a flexible and light-handed regulatory approach towards Mobility as a Service platforms

Given the substantial potential benefits of MaaS for accessibility and mobility, transport authorities should regulate only as necessary to facilitate the development of MaaS in line with public policy goals. Authorities should carefully monitor that MaaS developments do not hinder policy objectives. Regulatory or other appropriate interventions may be needed to ensure that the development of MaaS contributes to, rather than impedes, sustainable urban mobility and accessibility policies. In a MaaS system with commercial actors, a flexible and light-handed approach will be required to maintain the commercial viability of MaaS models as the market matures. Regulators should only adopt new regulatory requirements where there is clear public policy justification.

Adopt a predictable regulatory approach and allow for evolution

Trying to legislate *ex ante* or too early in an evolving and maturing MaaS ecosystem risks locking in regulation that is not fit for purpose, or suppressing innovation entirely. Built-in review periods and robust monitoring requirements provide space for the market and its actors to mature while still allowing the ecosystem to evolve. In parallel, mobility operators and MaaS providers require legal certainty and a clear and dependable regulatory framework to make investments in low-margin mobility markets. Regulators should facilitate the deployment of MaaS ecosystem building blocks – like common digital identifiers, interoperable data exchange standards and data-sharing rules that support market development – rather than trying to define a comprehensive and definitive MaaS model. They should also work to increase predictability around how, and under what conditions, regulatory frameworks might evolve.

Enhance public transport authorities' and operators' ability to negotiate terms of sale and re-use of tickets with Mobility as a Service providers

To facilitate a mode shift from private cars, the MaaS ecosystem should make public transport as accessible as possible. The relationship between public transport and MaaS can be symbiotic if MaaS platforms are able to increase public transport ridership. Public transport authorities and operators could benefit from greater freedom to negotiate fair and reasonable terms of sale and reuse of public transport services with MaaS providers. These negotiated outcomes would allow public authorities to retain their ability to achieve policy goals via their fare policies. This will require specific competencies on the part of public transport authorities and operators as well as oversight to ensure that negotiated outcomes do not erode public policy outcomes.

Base data-sharing frameworks on the principle of "as open as possible, as closed as necessary"

Some data must be shared for MaaS to work. Setting a transparent and fair basis for this sharing helps market actors build trust in the system. Minimum sharing requirements can help limit the amount of data required for participation in the market. Conditional reciprocity should be part of data sharing frameworks so that parties in the market gain some value in return for the data they share. Open access to market players should be encouraged as much as possible, but there must be fair commercial terms.

Build data portability into the MaaS ecosystem by default

Digital service markets depend greatly on data. This raises the risk of data-related lock-in of consumers to specific service providers, or to one provider only. Enforcing data portability requirements in the MaaS ecosystem facilitates consumers switching from one service to another or their use of multiple services. As there is no natural incentive for any single operator to push for this, it will be up to public authorities to define minimum data portability requirements. These requirements should be limited to data about the data subject but not to data inferred about the subject, and should be conditioned on data subject consent.

Consider common building blocks for sharing data

While a single, mandated standard for data exchange may prove restrictive, the absence of a common syntax could hinder interoperability; create the financial burden on smaller operators of compliance with larger providers' bespoke standards; or, paradoxically, impose on all market actors the costs of complying with multiple standards. Some form of standardisation and shared definitions would help overcome or mitigate these risks. In the absence of a single standard, ensuring that syntaxes share similar functional architectures enhances interoperability.

Establish data-reporting requirements that are proportionate and targeted to outcomes

Governments have the power to compel stakeholders' actions, by setting conditions on market entry and exit and by imposing penalties, for example. This should be counterbalanced with purposeful and limited data-reporting mandates aimed at achieving specific public policy outcomes. Such mandates will build trust between partners who are assured they are only being asked to share data that are necessary and proportional to their end-use. This will require a mapping of what data are needed, for what action, and for how long.

Adopt complementary policies in other areas to ensure that the Mobility as a Service ecosystem contributes to desired policy outcomes

MaaS is not a silver bullet for shifting to sustainable alternatives to the private car. Improving existing infrastructure and services, and complementing the "pull" of MaaS with "push" policies in other areas are preconditions for MaaS ecosystem's broad scale success. Users need a reliable, high-quality transport system as a baseline, and would further benefit from knowing the real costs involved with available transport choices. Authorities could introduce complementary measures that more clearly signal the externalities for drivers – e.g. congestion pricing, environmental charges or differentiated parking prices. These complementary policies foster the development of viable MaaS business models and their contribution to improved welfare outcomes.

Invest in the built environment and interchange facilities

MaaS can only be as attractive as the transport services that underpin it. High-quality services are needed, but so are comfortable, safe and attractive surroundings if people are to be enticed out of private cars. In particular, the role of interchange hubs and facilities are key. Authorities should recognise this as part of their planning in support of MaaS.

Skill sets will need to evolve to improve the public authority's capacity to regulate and assess digital markets

Local and transport authorities have been concerned primarily with the management of physical networks. Digitalisation, including that brought on by MaaS, challenges the skills usually involved and requires new institutional capacity to better manage digital markets. Skills now required include better digital literacy, more data-driven and flexible decision making, and a more commercial mindset. Upskilling may also be required for SMEs, including taxis and bus service providers, when these have not already digitised their service offering.

Overview

Urban mobility is at a crossroads. On the one hand, tremendous accessibility gains over the past century have opened up new horizons for billions of people around the world. Leaps in technology, infrastructure and energy production have enabled these gains. More people travel, further and faster, than at any other time in history, fuelling worldwide economic and social advances. But this has come at a cost with regard to safety, health, equity, efficiency, and local and global environmental threats – the most fundamental of these being global climate change. The benefits and impacts of mobility are concentrated in cites, which raises questions about how it is possible to continue enjoying the benefits that mobility confers while minimising its negative impacts.

*The Covid-19 pandemic has caused immense disruption to urban mobility***.** The pandemic will have significant short-term, and possibly medium-term impacts. The extent of these impacts is still uncertain, but the pandemic has reinforced the need to choose mobility policies that create resilient transport systems. A broader offer of mobility services – and deeper integration of these – will help build resilience by creating modularity and adaptability, and by fostering cohesion among mobility system stakeholders.

A growing world population combined with fast-paced urbanisation will increase transport demand in cities. Total urban passenger demand is projected to grow by 59% to 2030 and by 163% to 2050 from 2015 levels under a baseline scenario, even accounting for the effects of the Covid-19 pandemic. In most cities, individual motorised transport represents a significant share of all trips and the majority of passenger kilometres travelled. Globally, 51% of global urban passenger-kilometres travelled in 2015 were driven by private vehicles. Under all scenarios developed by the ITF in its 2021 Transport Outlook (ITF, 2021), Asia remains the highest generator of urban transport demand.

Public transport, active mobility, shared mobility and Mobility as a Service all are essential to mitigate the impacts of growing transport demand in cities. The ITF has looked at alternative scenarios that could deliver considerable decarbonisation of the transport sector. These scenarios suggest that, in addition to the effects of electrification, integrated land-use planning and transit-oriented development are particularly effective in reducing emissions, by shifting shorter trips away from private cars. These scenarios also assume strong growth in active modes (walking, cycling, etc.), shared mobility and public transport. The pathway to lower emissions builds on increases in load factors and fuel efficiency, which contribute to halving emissions by 2050. There are limits to vehicle technology-led emissions reduction; in particular, self-driving cars and electric vehicles alone are no panacea for curbing emissions. ITF modelling indicates that new forms of shared mobility services have great potential to reduce the need for private cars and reduce emissions. These shared modes also allow faster adoption of clean technologies. Integration of services is an important component to realising a lower carbon future for urban transport. It contributes an additional reduction in CO_2 emissions of approximately 5% by 2050, on top of already deep reductions.

A one-size-fits-all approach to addressing the benefits and challenges of urban mobility cannot work. Mobility needs vary by geography and population; global regions display significant differences in terms of urban transport mode shares and travel behaviour. Urban areas differ in levels and distribution of wealth, as well as in the scope and scale of technology deployment and uptake. Mobility services deployed in these different contexts will not have the same impact on travel demand and may give rise to either synergies or competition among modes depending on local conditions. A number of factors such as population, income, urban density and the presence of and interplay between public transport and informal transport services will define the impact of new mobility services.

A new approach to mobility encompassing, but moving beyond sole dependence on, the car is necessary. Everyday mobility is the result of interconnected, durable and deeply embedded factors that extend far beyond the confines of the transport sector or the urban context. This is especially true when considering the role of the car in urban areas. Addressing global urban mobility challenges will require rethinking the link between urban mobility and car use, and that will not be straightforward. A significant share of the world population aspires to have access to a car though most people still do not have such access. Conversely, countries that have motorised earlier and where car penetration rates are high are starting to explore shifting away from a singular focus on car use in urban areas.

The mobility landscape in cities is evolving rapidly and is characterised by new layers, more choices and more digital components. The same urban mobility landscape is shared by established incumbents and emerging mobility services, leading to synergies as well as tensions. In most cities, the tensions are exacerbated by the lack of a unified framework addressing all urban mobility services.

Efforts to change mobility must account for entrenched practices and system inertia. It is unlikely that simply offering an alternative to existing practices will trigger a shift in individual behaviours or a change in macro-level trajectories. The "system of provision" that results in the current car-oriented urban mobility practices is deeply embedded and must be accounted for in seeking to facilitate the uptake of new options. Effectively charting a way forward will involve arbitration among different views held by urban mobility stakeholders. These differing views reflect, among others, the optimism some have for technology-led approaches – and electromobility in particular – the prominence of the role that others believe collective transport must play, and the emerging view that better planning can maintain access to opportunities in urban areas with lower overall travel volumes.

Shared mobility is not necessarily green mobility. Calibrating the regulation of new mobility services requires an understanding of the external impacts these impose on sustainability. The operational profiles of mobility services, in addition to the vehicle technology used, has a strong impact on the sustainability of these services. Ride-sourcing services and taxis have higher CO_2 emissions per passenger-kilometre than all other mobility options. Shared electric micromobility and motorised 2-wheeler services have a much lower impact than ride-sourcing, taxis or individual car use; they are about on par with privately owned mopeds and bus-based public transport. Privately owned bicycles, e-bikes and e-mopeds have the lowest life cycle emission profiles per passenger-kilometre, followed by various forms of rail- or bus-based public transport (at typical load factors) and privately owned mopeds.

The impact of the broad uptake of new mobility services is directly linked to whether these substitute or complement other services. The evidence base for this is still developing but these effects are highly context-dependent. Ride-sourcing likely contributes to increased vehicle travel and congestion under current contexts and models. Additional interaction effects between ride-sourcing and other modes are not clear but ride-sourcing seems to compete with rather than complement public transport. Shared electric micromobility trips mostly replace walking, public transport and taxi trips. These are important effects to bear in mind when considering how and where it makes sense to integrate these modes into the urban mobility mix.

Mobility as a Service promises significant benefits from integrating mobility offers. MaaS proposes a more user-centred mobility paradigm to travellers, by facilitating more efficient use of underutilised transport assets and public space, and by creating new opportunities for firms and other actors to find and develop new markets. These efficiencies could contribute up to 15% of overall CO_2 savings from urban mobility by 2050 compared to scenarios without shared mobility and MaaS.

MaaS should be seen as a distribution model for mobility, not as an app or a travel mode. MaaS is a model for supplying passenger transport services through a digital customer interface that allows users to source services from a variety of operators, either privately or publicly operated. At its core, MaaS seeks to provide a smooth and reliable customer experience. MaaS involves identifying clients and operators, gathering information about the availability of services and capacity, and managing payment and revenue allocation within a common digital framework. It requires the production of mobility services by public and private actors, joining these into an integrated offer and a means to communicate this offer to potential travellers.

MaaS is characterised by levels of operational, informational and transactional integration. MaaS is still very much an evolving concept and its implementation falls along a continuum of operational, informational and transactional integration. MaaS implementation and ecosystems may evolve over time as they grow or achieve greater integration. There is considerable heterogeneity in MaaS service levels and offers – sometimes even in the same market. The integration need not cover the entire mobility market – there may be models for MaaS that only provide partial integration within these three domains, or full integration only among some mobility service providers.

MaaS may enable new value creation in low-margin urban mobility markets. Urban mobility is a capital-intensive low-margin network market in its current form. There are limitations to the amount of economic value that can be captured by commercial actors while still delivering on public policy outcomes under existing market structures. Up-front investments in infrastructure and rolling stock, provision of networked services that cover a broad geographical area, and the cost of meeting high environmental and social standards while offering affordable and universal coverage all put pressure on margins. This pressure leaves little room for MaaS providers to find sustainable revenue streams under current market configurations. Commercial success for MaaS providers will likely require creating new value propositions. This value may be additional to what is currently in the market and may be derived from people or employers who are willing to pay for the benefits MaaS would confer on them. It may also come from reducing costs for public authorities, or it may extend to non-mobility offers that allow operators to achieve remunerative margins drawing on multiple revenue streams.

MaaS business models are evolving. Business models for MaaS are nascent, involve interactions between settled service delivery models and emerging ones, and are developing under unclear, longer-term market dynamics and regulatory frameworks. They also create a new category of mobility actor – the MaaS service provider or aggregator – and that has implications for the organisation and regulation of these markets. The economics and business models for mobility service providers are better understood than those of MaaS aggregators.

Multiple MaaS market configurations exist and it is too early to tell what final configurations the market may have. These configurations cover business-to-consumer, business-to-business and business-to-government-to-consumer interactions. Of these, the business-to-business configuration seems to have a more immediate pathway to achieving returns but requires government action with respect to company mobility management policies.

Business models for MaaS aggregators may involve closed and vertically integrated services – "walled gardens" – which may deliver innovation but stifle competition; public MaaS aggregators that draw on strong networks but that come with risks of protective incumbency positions; an open but publicly regulated back-end platform serving the entire MaaS ecosystem; or a platformless ecosystem built on direct and instantaneous transaction clearing employing distributed ledger technology. Other models may yet develop as well, as the market matures.

For MaaS to grow, people must choose it over other travel options – this will not be a simple matter. Individual characteristics are significant, though they alone do not determine travel choices. MaaS uptake should also address cognitive decision-making processes, real or perceived mode and service attributes, and the framing context for travel decisions. Evidence suggests that it may be unreasonable to expect that MaaS will provide a compelling substitute to car ownership for a broad segment of the population at the outset. Rather, it may be that MaaS may serve as a complement to prevailing car use by providing a real alternative for some but not all trips made by car.

MaaS alone is not sufficient to deliver on the public policy aspirations it inspires. MaaS alone, without a supportive built environment and high-quality public transport system, will likely not succeed in changing behaviour, whereas improving the built environment and transport system may lead to changes in travel behaviour even without MaaS. Furthermore (and paradoxically), when the built environment and the level of quality of public transport and active travel modes are truly high, there are likely to be smaller potential returns on investments in support of MaaS, thus limiting the commercial appeal of deploying such services.

The outlook and scaling challenges for MaaS differ across regions. Good-quality public transport is not as widespread in North America as in Europe or in some Asian cities, and this will likely shape the rollout of MaaS there. The conflation of mobility as a service into a broader "service as a service" ecosystem and "super-apps" is rapidly developing in Asia. Another MaaS-related development in Asia is the uptake of diversified and hybrid mobility services using two- and three-wheeled vehicles to move people and goods. The deployment of these services highlights the tension that exists between the affordability of public transport systems and the limited scope for public transport to provide adequate levels of access in sprawling and congested cities. Japan presents a unique case where national government policy has sought to explore and adapt different MaaS models to specific targeted outcomes. The motivations for seeking to develop MaaS in Japan are diverse and typically go beyond simply wanting to mitigate the traffic, equity and environmental impacts of car use in urban contexts.

The regulation of MaaS ecosystems involves two components – the regulation of mobility services/operators and the regulation of digital platforms and MaaS aggregators. It also requires a supportive policy framework. The regulation of mobility services/operators is a challenging yet familiar terrain for transport authorities, but many aspects of digital market regulation are uncharted at the regional and local levels where much of the regulatory framework for MaaS will be set. A well-functioning market will also require a supportive policy framework and accompanying measures (e.g. addressing data regulation, pricing, urban access management and adapted multimodal infrastructure).

MaaS requires a regulatory foundation that enables innovation and delivers on policy outcomes. MaaS is an evolving concept that has the potential to create value for people and deliver on public policy outcomes while enabling healthy market opportunities for various stakeholders. It requires adapted forms of regulatory guidance but where and how much are still not settled. It therefore seems premature to talk about what the regulatory framework should look like, as both MaaS and its regulation are likely to evolve over the near term. Furthermore that framework will differ across countries and urban contexts. Nonetheless, MaaS regulation should be guided by principles that are tested and well understood in other, analogous markets, even though their direct transposition to MaaS may not be suitable without adjustment.

Aspects of digital service markets in MaaS raise challenges that mobility regulation has yet to address effectively. These relate to characteristics of digital markets such as extreme returns to scale, network externalities and incumbency advantages, the role of data and the regulation of digital platforms. Some of the competition policy risks that stem from poorly addressing these issues in regulation are somewhat tempered by the fact that MaaS services have physical components (vehicles and infrastructure and their uses) that are regulated. Nonetheless, the regulation of MaaS aggregator services will dedicated approaches.

Revenue sharing in MaaS markets is difficult. Revenue sharing in a MaaS ecosystem appears substantially more complex than revenue sharing among public transport operators, and there are risks that strong lobbies representing incumbents may resist integration. Furthermore, the fairer an attribution model, the more complex and expensive it will become. The diversity of business cases operating models among mobility service operators contributes to diverging interests in key areas. Revenue attribution models that could guarantee an acceptable distribution would likely be inefficient and expensive. Transport service providers' willingness to engage in such schemes is limited by already tight profit margins.

The imperative to travel better

Mobility delivers opportunity

Mobility is essential to improve human welfare, especially in urban and peri-urban areas where the majority of the world's population is concentrated. People crowd into cities and towns because communities concentrate opportunities, access to goods and capital, cultural activities, living, working, and "making" spaces. These elements generate economic, social and cultural growth and have maintained the global trajectory towards sustained increases in prosperity. Because these activities and opportunities are spread out in space, communities generate a need for mobility so that people may gain access to these (Crozet, Santos and Coldefy, 2019; ITF, 2021b).

Accessibility is the metric that measures mobility and combines activities, location and movement into a unified indicator. The more activities and opportunities that can be accessed within a given amount of time (and/or budget), the more economic activity is generated and the more efficiently communities produce economic growth – up to the point where negative impacts linked to density or movement overwhelm the benefits (ITF, 2019). Accessibility confers important social benefits as well, which support social well-being and prosperity even if they do not contribute to economic growth *per se.*

Given decades of sustained growth in economic prosperity, transport has clearly contributed to improved access to opportunity for all – but not always to all in equal measure (Guo et al. 2020)(SUM4ALL, 2021). One of the main drivers of this contribution to improved outcomes in urban areas has been the range of motorised transport technologies that have underpinned the growth in travel over the past hundred years. Successive technological revolutions and large-scale structural shifts in the energy sources fuelling transport have directly contributed to growth by widening accessibility. These revolutions have moreover indirectly generated economic activity linked to the manufacture of vehicles and supportive infrastructure as well as the sourcing, processing and transport of fuel and other energy sources. These broad benefits have accrued globally but have not been evenly distributed across or within regions and over time (Guo et al., 2020; SUM4ALL, 2021).

The digital revolution has probably not shifted the fundamental benefits derived from mobility. The broad uptake and ubiquity of information and communications technology has had a deep and disruptive impact on transport. These shocks are still playing out, but they have already fundamentally challenged several existing service delivery and business models in the transport sector. They have also called into question fundamental assumptions about travel behaviour; the linkage between work, location and productivity; and the future of travel. While much is possible – especially in the long run – there is considerable inertia in mobility patterns and practices that dampens sudden shifts (ITF, 2021a).

Personal mobility is highly valued around the world but this attraction is tempered by other valued outcomes. The abiding attraction of personal mobility is not the sole domain of the car though generally, as incomes rise, individuals favour bicycle, motorised two-wheeler and, ultimately, car ownership (Dargay et al. 2007). This trajectory is not uniform across populations and regions, nor is its end-point in terms of car ownership necessarily fixed. However, there is an lasting common trend towards more car ownership as incomes rise across global metropolitan areas (Trouve, Lesteven, and Leurent 2020). This desire for more personal and individual mobility plays out against a backdrop of other desired outcomes – first among these is the desire to live in metropolitan regions characterised by high levels of accessibility (MIT, 2019). Achieving these other outcomes tempers attraction towards the use of individual motorised vehicles and in some cases their ownership. Further, contextual factors including urban design and land-use patterns; availability of infrastructure and/or high-quality transport alternatives; and supportive fiscal and other policies may divert this trajectory towards other forms of personal mobility (e.g. bicycles in the Netherlands, motorised two-wheelers in Southeast Asia, new mobility services or informal transport in many cities) and public transport (MIT, 2019).

Mobility faces several sustainability challenges

The nature of our mobility practices, the technologies and energy sources on which these rely and the scale of transport activity are not sustainable. Transport technologies have generally increased speed and travel time savings. Higher speed travel benefits travellers but also generates external costs that are borne by society (Santos et al. 2010). These external costs are variable in scale and across contexts but one is global and imposes an existential threat – the cost imposed by global climate change.

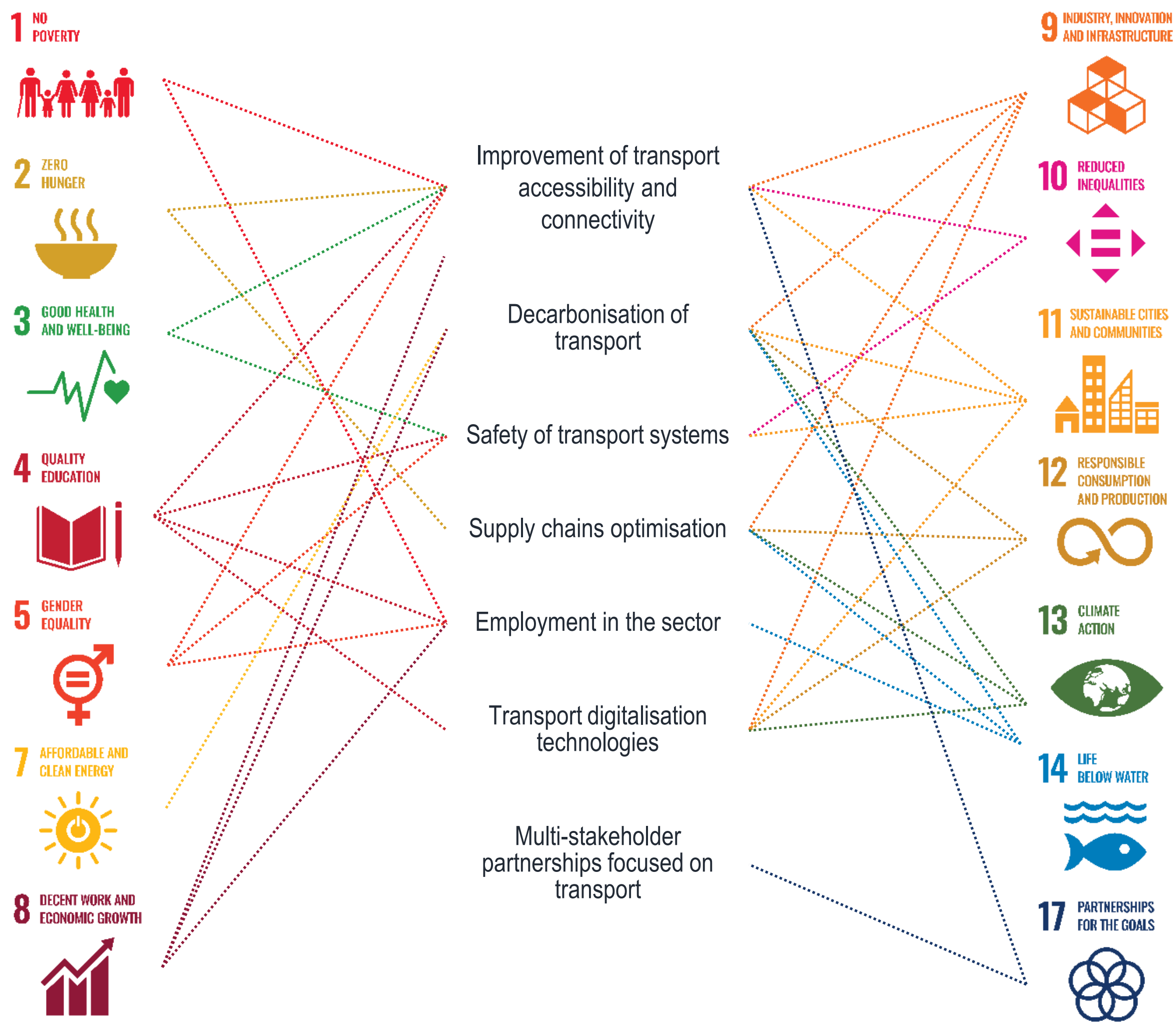
Transport's contribution to global climate change is significant and growing, making it a priority in addressing climate change. Transport represented 25% of direct CO_2 emissions from fuel combustion in 2018 (IEA, 2020). These emissions increased at a compound annual growth rate of 1.9% per year from 2000 to 2020 while other sectors, industry for example, have experienced a drop in emissions. Despite a dip in emissions linked to successive Covid-19 lockdowns and travel restrictions – which the ITF estimates has led to a 15% year-on-year drop in transport CO_2 emissions in 2020 – the trend in transport-related CO_2 emissions growth is likely to continue to be fuelled by gains in wealth, rising travel demand and freight transport through to 2050 (ITF, 2021). Urban passenger transport is an especially significant contributor to CO_2 emissions, representing 40% of all passenger transport greenhouse gas emissions and 24% of all transport CO_2 emissions. Reducing urban transport's dependency on cars and other private vehicles is key – these represented three-fourths of all GHG emissions from urban transport in 2015 (ITF, 2021).

Transport also imposes significant external costs in other important domains. These include congestion and the costs linked to fatal and injury-causing crashes, to reduced health (from emissions, noise and decreased physical activity), to paving permeable soils and surface water runoff, to climate change, and to habitat degradation and loss of biodiversity. Upstream costs linked to the production of energy, vehicles and infrastructure are significant as well. These combined costs represent for example EUR 987 billion in 2016 in Europe alone (Schroten et al., 2019). In addition to these, motorised mobility – either public or individual – has crowded out walking, cycling and other active forms of mobility which deliver great mobility and health outcomes just as it has crowded out alternative uses of public space in urban areas.

Overcoming these challenges will require going beyond an access-only lens. While mobility delivers access to opportunities, the way in which it does this determines its contribution to sustainability and should serve to guide and filter policy. Sustainable Mobility for All (2021) identifies four essential objectives which, if achieved, ensure that meeting the mobility needs of the current generation do not impinge on the ability of future generations to meet theirs. These attributes are universal access, efficiency, safety and minimised environmental impact.

Universal access means designing technologies, infrastructure and networks and deploying transport services and policies that ensure that all can benefit. At a minimum, this means ensuring a basic level of access that is affordable and available to all. Framing mobility policy around universal access is a way of ensuring that segments of the population that have suffered from poor physical or spatial access – especially women, low income groups, the young, the old, the disabled, the vulnerable, and those living in rural areas – are able to contribute to, and benefit fully from, society (ITF, 2021a) While the focus of this report is on urban areas, in many countries significant portions of the population live in rural and peripheral areas.

Figure 1. The relevance of transport for the UN Sustainable Development Goals



Note: The content of this publication has not been approved by the United Nations and does not reflect the views of the United Nations or its officials or Member States.

Source: United Nations (2021).

Transport demand should be met efficiently and at the least cost. This focus on efficiency encompasses two broad domains – optimisation of resource use and effectiveness of regulation and market organisation. The former covers the resources necessary to operate transport services and networks including energy, technology, time and space. Regulatory and market efficiency ensure that citizens' expectations and consumer outcomes are delivered effectively, fairly and transparently. A sustainable transport system should seek to eliminate inefficiencies and free up resources for more productive uses.

At the same time "at least cost" does not mean "at low cost" – providing a basic level of access means developing convenient and reliable options and good-quality services. These are often expensive.

Safety should be paramount in efforts to achieve sustainability outcomes for transport. Mobility practices should be designed to prevent any fatalities and to drastically reduce injuries and damaging crashes that place a tremendous human and economic burden on society. Approximately 1.35 million people die per year as a result of road crashes worldwide, with pedestrians, cyclists and motorcyclists representing over half of these. Ninety-three percent of these deaths occur in low- and middle-income countries even though these countries represent only sixty percent of the global vehicle fleet (WHO, 2018). Beyond road traffic deaths, crashes contribute to approximately 20 million to 50 million non-fatal injuries – many of them leading to disabilities and all of them contributing to welfare and economic losses (Chen, et al, 2019).

Mobility should significantly reduce its contribution to global- and local-scale environmental and health burdens. The bulk of transport activity requires direct and indirect fossil energy inputs. Global climate change presents a generational sustainability challenge, as the impacts of global warming are large and irreversible in the short to medium term. These risks encompass health, economic livelihood, food security, water supply, human security, and economic growth (IPCC, 2018). Additionally, regional and local-scale impacts stem from the emission of pollutants, fine particulate matter, noise and erosion of ecosystem function and viability. These are equally important and have immediate tangible negative impacts – for example, vehicle-related air pollution contributes to approximately 184 000 premature deaths and a considerably greater number of victims of longer-term pollution-related ailments (Bhalla et al., 2014).

Transport is central to delivering on the UN Sustainable Development Goals. These goals outline 17 key areas where action is necessary to support more sustainable societal outcomes. Transport is directly or indirectly linked to meeting many of the SDG goals as illustrated in Figure 1.

Meeting mobility's challenges must account for context

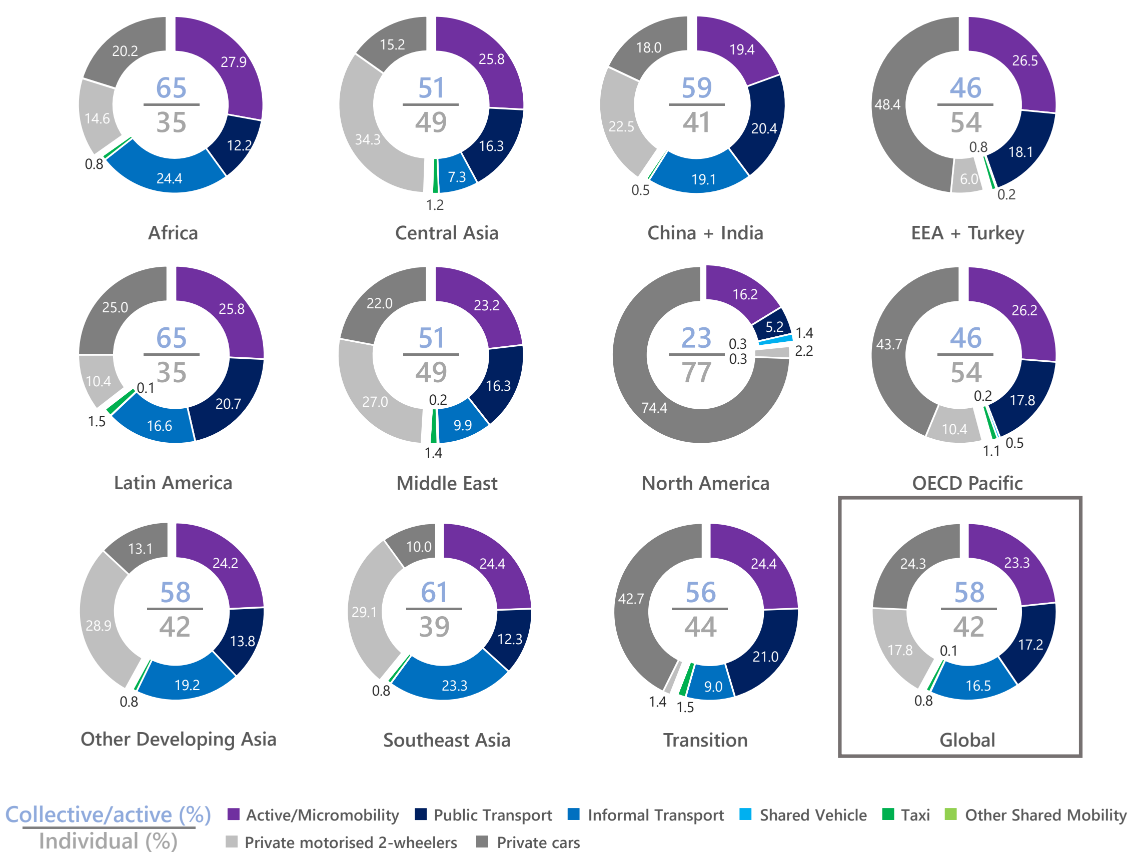
A one-size-fits-all approach to addressing the benefits and challenges of urban mobility cannot work. The benefits and burdens of mobility are not evenly spread among populations, countries or world regions. Improving the sustainability of mobility must account for these differences and address the systemic inertia embodied in current mobility systems.

Mobility is not experienced uniformly across different spatial contexts and different types of communities. Communities are multifunctional spaces, and increasing speed or managing public street/road space to deliver improved traffic efficiency only for certain vehicles may erode other valued benefits associated with those spaces (commercial retail activities, informal street commerce, use of pavements and sidewalks for dining or shopping, quiet frontage space for residential buildings, etc.). These knock-on effects should be accounted for when framing mobility initiatives.

Global regions display significant differences in terms of urban transport mode shares and travel behaviours. ITF analysis of global urban travel activity reveals varied starting points in terms of the offer and use of different urban transport modes. These are linked to wealth and local contexts. ITF estimates that globally, 58% of all urban trips are taken by collective/active modes and that these modes dominate in 8 out of 11 global regions (Figure 2).

Public transport on its own is never the primary trip mode across regions but, when combined with informal transport, it represents the primary mode globally and in 5 out of 11 regions. Active transport and micromobility (mostly walking) is a consistent feature of most urban travel in global regions with the exception of North America and The People's Republic of China + India, representing about a quarter of all trips. Finally, while the car represents the primary urban trip mode for North America, the EEA + Turkey and Transition countries, the use of motorised two-wheelers is significant in a number of world urban regions – notably in Asia and the Middle East. These different starting points matter in terms of future urban mobility development. Car motorisation rates are likely to rise as incomes rise, following past patterns. However, car motorisation endpoints might very well differ in late motorised regions as compared to early motorised regions, especially considering that the mobility offer characterising the early 21st century will be different from what was on offer in the middle of the 20th century.

Figure 2. Urban trip mode share by world region in 2015 (percentage of urban trips)



Note: EEA refers to the European Economic Area. LAC refers to Latin America and the Caribbean. MENA refers to the Middle East and North African countries. OECD Pacific countries include Australia, Japan, New Zealand and South Korea. SSA refers to sub-Saharan Africa. Transition economies include countries that were part of the Former Soviet Union and non-EU south-eastern European countries.

Source: ITF (2021).

Urban areas differ in levels and distribution of wealth as well as in the scope and scale of technology deployment and uptake. These differences influence mobility practices as well as the viability of different business models. MIT (2019) describes six sets of city mobility types for 331 of the largest urban areas in the world (with populations over 750 000) that share key identifying features distributed along a range:

- *Mass Transit Heavyweight* cities have the highest public transport usage (rail- and Underground-based) and second highest wealth scores. Many have relatively high bikeshare penetration. They are characterised by extensive transit-oriented development patterns. Most of these cities are in

Europe alongside large cities in Japan and elsewhere (Singapore, Hong Kong and some outlier cities in North America such as New York and Vancouver). Mass Transit-moderate cities are smaller yet still relatively dense and structured around well-used public transport networks. They too have significant bikeshare penetration. These cities are concentrated in Europe alongside cities in Israel. Together, moderate and heavy Mass Transit represent 15% of the 331 cities studied.

- *Auto Sprawl* and *Auto Innovative* cities mainly refer to urban areas found in North America and a few other locales. These cities are dominated by car use accompanied by sprawling urban land form with regard to the former while the latter are characterised by higher land-use density and rail-based public transport availability. These cities represent 20% of the 331 cities studied.
- The *Congested Boomer* archetype describes rapidly developing and congestion-prone megacities with low rail- and Underground-based public transport availability. These are notably found in India. *Congested Emerging* cities describe urban areas that are on a trajectory to becoming *Congested Boomer* cities as they continue to grow and urbanise rapidly. Many of these are found in sub-Saharan Africa. These cities represent 23% of the 331 cities studied.
- *Hybrid Giant* cities are urban areas characterised by a relatively uniform mode share distribution, dense networks and high population density. Hybrid moderate cities share roughly the same mode share but with less dense networks and lower population density. Both Hybrids are notably found in Central Asia, Latin America and Eastern Europe. These cities represent 14% of the 331 cities studied.
- *Metro Bike Emerging* and *Metro Bike Giant* cities are found exclusively in China and are characterised by high availability of bikeshare services alongside very dense and extensive public transport networks. The two categories are differentiated in terms of population size. These cities represent 10% of the 331 cities studied.
- *BusTransit Dense* and *BusTransit Sprawl* cities are largely found in Latin America and are characterised by the deployment of bus rapid transit (BRT) systems. They are differentiated by population size, network density and compact versus sprawling land-use patterns. These cities represent 19% of the 331 cities studied.

Mobility services deployed in these different contexts will have differing impacts on travel demand, and may give rise to either synergies or competition among modes depending on local conditions. Potential outcomes from the deployment of new mobility technologies and services must be seen in the context of these (or similar) groupings.

The deployment of automated on-demand mobility services in automobile-dependent prototype cities (Auto Sprawl and Auto Innovative urban archetypes, essentially in North America) would siphon trips away from public transport and lead to an increase in overall car vehicle kilometres travelled and congestion.

City-specific modelling exercises in Europe and New Zealand undertaken by the International Transport Forum (ITF, 2021d) suggest there are synergies between shared mobility, core public transport services and the potential for reduced congestion and improved accessibility and sustainability outcomes. Further work undertaken by the ITF suggests that the introduction of new mobility distribution models, such as Mobility as a Service, will also have effects that differ by world region and city context. The sustainability of these is linked to threshold effects that mark the point at which the services start to change travel behaviour patterns on a discernible scale (ITF, 2021c). These differences underscore the emerging state of knowledge and evidence in this field as well as the need to carefully account for local context.

Current mobility practices are the tip of an iceberg

Everyday mobility is the result of interconnected, durable and deeply embedded factors that extend far beyond the confines of the transport sector or the urban context. New mobility practices build on these factors, just as policies seeking to change the trajectory of mobility must contend with the systemic inertia they impose. Much of the discourse around sustainability – including from some parts of the car manufacturing industry – points to the need to move away from singular dependence on the car for all needs, in all contexts and at all times.

A new approach to mobility is necessary, encompassing, but moving beyond the sole dependence on the car. Different types of personal mobility vehicles, different uses of cars, and more use of alternatives to the car – alongside energy efficiency improvements – all have a role to play in making mobility more sustainable. At the same time, increased access to cars and light mobility vehicles can also contribute to supporting sustainability outcomes in certain contexts (Rao and Min, 2018).

Efforts to change mobility must account for entrenched practices and system inertia. Moves to lessen the current state of car dependency in developed economies, or to inflect the trajectory towards car dependency in developing economies, cannot ignore the political economic "system of provision" entrenching urban mobility (Mattioli et al. 2020). This is especially true if commercial stakeholders or policy seeks to provide, encourage or facilitate the use of alternative transport modes or promote the "servicisation" of transport.

The "system of provision" that results in the car-orientation of current urban mobility practices has five components – addressing these together will facilitate the uptake of new mobility practices. The five work both independently and in combination with each other to make the use of cars compelling and, in many cases, necessary for accessing basic needs and improved well-being. These components are the automobile industry, the provision of car infrastructure, the political economy of urban sprawl, the provision of public transport, and cultures of car consumption (Mattioli et al., 2020).

- *The automotive sector is an essential actor in the discussion of sustainable mobility*. Any move to increase the "servicisation" of car-based mobility will have to understand, accommodate or otherwise address the vested interests of this industry. Efforts to shift the way in which the car industry realises value in a changing mobility context will have to contend with the organisational costs and frictions these efforts generate.

- *Infrastructure, rules and practices support car use in many urban contexts* (ITF, 2021). While individuals invest in cars and their operation, the public provides paved roads, public parking, traffic regulations – including rules relating to exclusive use of the roadway and operating speeds, licensing schemes and road safety policies. Efforts to diversify travel choices away from the car should not ignore the extent to which travel choices are embedded in the existing physical and regulatory context.

- *The uptake of individual motorised mobility has contributed to the sprawl of metropolitan areas*. Policies to shift car usage patterns in low-density contexts will not have the same impacts or effectiveness as in higher density areas.

- *Increase in car travel has physically crowded out walking and cycling and has been accompanied by a decrease in public transport use.* Efforts to shift travel behaviour away from overdependence on cars cannot ignore the level, scope or quality of public transport provision. In most cases, public transport provision may deliver societal benefits but these are not commensurate with the benefits individuals derive from car use.

- *The value that people derive from car use is not just utilitarian – the car is a complex product that bundles multiple attributes.* This is not exclusive to car use – cyclists, pedestrians and public transport users all display similar behaviour. This suggests that change requires targeted action aligned with people's aspirations and not just their travel needs.

Because of these factors, simply offering an alternative to existing practices is not likely to trigger a shift in individual behaviours or a change in macro-level trajectories. Despite the urgency of certain challenges, change is not likely to occur rapidly. Nonetheless, inflection points can be triggered now that will have consequential outcomes. These inflection points include changes in pricing and taxation, alternative infrastructure provision or space allocation, better targeting of policy and improved monitoring and feedback loops, as well as improved integration of travel services. These policies must be deployed with a real understanding of system inertia and the need to co-ordinate actions across a range of actors whose views of sustainable mobility may not converge.

Achieving sustainable mobility requires arbitration

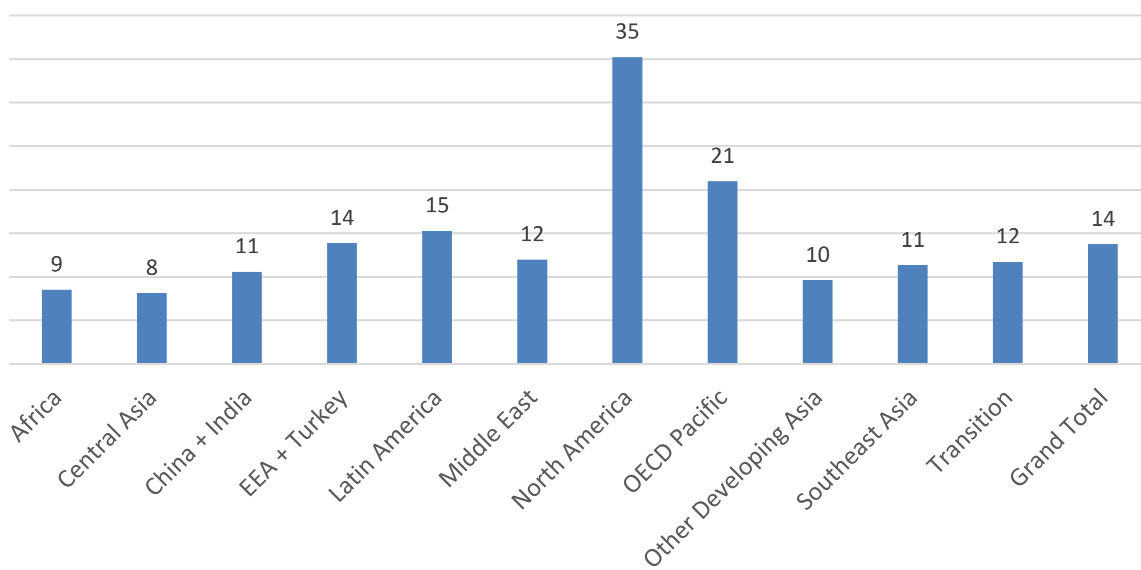
Achieving sustainable mobility is a "wicked" problem and addressing it will require collective arbitration among stakeholders and their views. Complex societal challenges like that posed by simultaneously greening transport and ensuring it equitably contributes to economic and social outcomes are described as "wicked problems" (Churchman, 1967). These problems are tough because they involve multiple stakeholders with different worldviews and contradictory objectives, and because there is no shared agreement on the problem at hand. There are however many ways to articulate stakeholders' views in this kind of arbitration. Building on more than 30 years of sustainable mobility policy discussions, Holden et al. (2020) focuses on three grand narratives that help to establish a basis for debate: *Electromobility*, *Collective transport 2.0* and *Low mobility society*.

The broad *Electromobility* narrative is generally easy for most mobility stakeholders to navigate (Holden et al., 2020). While it represents an upstream shift in energy production, storage and delivery – as well as a need to deploy adequate charging infrastructure – it does not fundamentally challenge the dominant model of individual, car-based mobility. It promises to deliver on many of the aspirations embodied in the car narrative (e.g. freedom, convenience, status) while addressing some of the negative externalities associated with fossil fuel use. It nonetheless also inherits some of the challenges of the existing car-based model, relating to safety and congestion for example. The car-focused electromobility narrative seems best suited to urban contexts characterised by lower land-use density, sparser and lower-quality public transport services, and more diffuse travel patterns – e.g. the *Auto Sprawl* and *Auto Innovative* city archetypes described earlier. However, even in those contexts, car-based mobility represents significant costs for households and a good number of households have no access to a car (e.g. 9% in the United States in 2019 – US Household Travel Survey). When the electromobility narrative is expanded to include a much broader range of small and light electrified vehicles, the narrative makes sense in many more urban contexts – e.g. the Mass Transit and MetroBike archetypes. These include some parts of Europe where light mobility infrastructure and speed management policies are well deployed, and China where these low-cost options are immensely popular in crowded and dense urban areas.

The *Collective Transport 2.0* narrative builds on a significant increase in collective transport alongside the deployment of various forms of shared and innovative mobility services (Holden et al., 2020). It is broadly suited to the types of hybrid public transport/shared mobility models described in various ITF simulation studies in Lisbon, Dublin, Auckland, Helsinki and Lyon (ITF, 2021d). This narrative faces significant scaling challenges due to the ambitious increase in public transport supply it suggests as well as the much broader adoption of shared mobility services than currently experienced even in the most favourable markets it calls for. It also faces acceptability challenges in that it represents a break with past aspirations for individual mobility in many global contexts. Nonetheless there are signs that, at least in dense urban settings, acceptance of and even attraction to more shared and collective transport may indeed be evolving – especially with the uptake of digitally accessed mobility services. The *Collective Transport 2.0* narrative has the potential to deliver on a broad range of sustainability outcomes, from reduced emission of greenhouse gases and local pollutants, to improved safety outcomes (linked to lower travel volumes), congestion reduction and improved mobility outcomes for those who cannot drive or do not have access to a car. These outcomes hinge on the extent to which collective and shared mobility substitutes for existing car-based travel. This kind of narrative is best suited to all the city archetypes described earlier that have not yet settled around high levels of automobile dependence.

Figure 3. Daily urban travel distance per capita across global regions

(Kilometres per person in 2015)



Note: EEA refers to the European Economic Area. LAC refers to Latin America and the Caribbean. MENA refers to the Middle East and North African countries. OECD Pacific countries include Australia, Japan, New Zealand and South Korea. SSA refers to sub-Saharan Africa. Transition economies include countries that were part of the Former Soviet Union and non-EU south-eastern European countries.

Source: ITF (2021a).

The Low-Mobility Society narrative is likely to fit those contexts characterised by higher density and broader accessibility that enable low car use lifestyles (Holden et al., 2020). There is evidence indicating a wide disparity in daily travel distances across different urban contexts (Figure 3). In that respect, many lower-mobility societies already exist and though travel distances will tend to rise as incomes do. Nonetheless, the final volume of travel is likely to differ according to urban contexts, land-use densities, land values and available opportunities and amenities. Structural changes in working patterns, including a shift from production to service industries and an uptake of telework, may have an impact on daily urban travel distances. The re-localisation of daily travel around home locations may decrease work commutes but may also increase overall travel as more frequent, shorter trips are made or as occasional commutes become longer with people re-locating further from their workplace. Comparisons between remote teleworkers and workplace commuters show that while a substantial share of teleworkers do not leave the home (20%), those who do travel more than their commuter counterparts (Su, McBride and Goulias 2021). The acceptability of low-mobility lifestyles is unevenly spread across urban contexts, age cohorts and income groups. Car-light cities – especially city centres – deliver clear benefits to residents but may also price inhabitants out to car-dependent peripheries. The deployment of convenient, compelling and affordable alternatives to solo car use should be as much a policy objective as facilitating a low-travel urban setting. Low-mobility urban areas have the potential to reduce greenhouse gas and pollutant emissions as well as to increase road safety (via lower risk exposure due to fewer vehicle kilometres travelled), but these effects may be eroded by an uptake of non-urban travel opportunities. The link between access and travel is not straightforward. High accessibility does not necessarily mean less travel but a low-travel society is probably most associated with high-density, mixed-use urban contexts that deploy light mobility infrastructure – like urban areas that fit the MassTransit, BusTransit Dense and Hybrid Giant archetypes described earlier.

Where are we now and what lies ahead?

The imperative to travel *better* underscores the need to achieve greater sustainability, resilience and equitability in everyday mobility. Meeting these objectives requires addressing the structural factors set out in previous sections as well as taking stock of where we stand now and the trends that are likely to play a role in future mobility practices. This stocktaking is at the heart of the International Transport Forum's *Global Transport Outlook*. This section reproduces and summarises the principal findings of that work as it relates to understanding urban mobility trends and future scenarios (ITF, 2021a). The findings draw on the ITF urban passenger transport model described in Box 1.

The Covid-19 reset

The Covid-19 pandemic has had a deep and sudden effect on global mobility patterns. Its impacts were swift – brutal in some cases – and lasting in their duration as communities and countries sought to juggle the twin imperatives of managing the health impacts of the pandemic while maintaining prudent levels of economic and social activity. This balancing act continues at the time of writing and, despite the deployment of various vaccines and improved prevention and treatment protocols, there is no certainty as to when or how communities will emerge from the acute phases of the pandemic.

The immediate outcome of sanitary containment measures and uptake of health protocols in cities and transport systems was a sharp drop in transport demand and a re-localisation of transport activity. This was accompanied by sometimes significant job furloughs and losses that may only be partially reversible in the short run as economic activity eventually picks up. Changes in the job market and employment levels will have reduced travel demand in the short term. The suppression of travel demand is not likely to last in the longer term though the scope of travel may change in response to the pandemic. In particular, the re-localisation of transport around homes and other remote work locations implies a short- to medium-term structural shift away from commuting activity for which public transport networks have been designed, and dimensioned towards less radial and more diffuse trip patterns for which traditional forms of public transport are poorly suited. This will likely aggravate the drop in public transport revenues and challenge its medium-term viability in many contexts. It may also represent new opportunities for the complementary deployment and uptake of other transport services better suited for shorter-distance travel in lower density areas.

Those in higher-paying service sector jobs migrated massively to home or remote working arrangements. Approximately 48% and 42%, respectively, of the workforce in the United States and European Union shifted to remote working (Sostero, et al., 2020; Bloom, 2020). Those whose work was incompatible with remote presence, especially in service and informal sectors, bore the brunt of job and revenue losses – especially women, who are disproportionately represented in these sectors (UN Women, 2020). This may have an effect on short- to medium-term travel demand, both in volume and in scope (ITF, 2021a).

Those not able to work from home also faced degraded access as public transport and informal transport operators cut frequencies and services due to lack of ridership (ITF, 2021d). In particular, essential workers with off-peak schedules – in health, transport, food, delivery and emergency services – faced difficulties in getting to work as public transport services were scaled back in some areas. Against this background, people turned to walking, cycling and shared micromobility, where these services were present and where safe infrastructure encouraged their use. Cities around the world rapidly deployed emergency light mobility infrastructure to facilitate this shift and to enable sanitary travel conditions in urban areas (ITF, 2021e).

Box 1. The International Transport Forum Urban Passenger Transport Model 2020

The ITF Urban Passenger Transport Model assesses transport supply and demand in all regions in the world. It does so for more than 9 200 macro Functional Urban Areas (FUA, a metropolitan area) worldwide.[1] It estimates trips, mode shares, passenger-kilometres, vehicle-kilometres, energy consumption and CO_2, SO_4, NOx and PM emissions for 18 modes[2] for the period from 2015 to 2050, in five-year increments. The current version enables an assessment of the impact of 23 policy measures and technology developments specified for each of the 19 regional markets included in the model. The ITF model was first presented in 2017 and is constantly updated and improved. Key features are described below.

Table 1. Key features of the ITF Urban Passenger Transport Model

	2019 version of model	2021 version of model
Urban population and cities	3.3 billion people in 11 099 cities.	3.6 billion people in 9 234 macro Functional Urban Areas[1] (FUA)
Demographic model	External input.	Internal demographic urban model representing population evolution for 36 age and gender groups[3] for each macro FUA.
Land-use evolution	For each FUA, a growth rate is estimated.	For each macro FUA, different growth rates are estimated for the macro FUA centre and for its suburbs.
Environmental performance	Average tank-to-wheel vehicle emissions based on the ICCT Roadmap Model for local pollutants and the IEA Mobility Model for CO_2.	Include both tank-to-wheel and well-to-tank CO_2 emissions based on the IEA Mobility Model (IEA). Includes local pollutants based on the ICCT Roadmap Model (ICCT).
Trip generation model	Average trip rates.	Trip rate calculated based on 5 distance, 5 age and 2 gender categories.
Estimation of car and motorcycle demand	Overestimation of car and underestimation of motorcycle passenger kilometres particularly in Asia and Latin America and the Caribbean.	Reduction of car passenger kilometres and increase of motorcycle passenger kilometres, resulting in similar total demand but lower CO_2 emissions in the related world regions.
Walk access and egress trip legs	Not considered.	Non-active modes include additional walking component for access and egress.

Where available, socio-economic and mobility data, including GTFS data, have been collected for the FUAs. Where unavailable, the model replaces missing data with synthetic data estimated using regression analysis from similar FUAs. Inputs such as GDP per capita, geographic area and energy costs are updated for each model iteration.

In each iteration, the model first updates transport supply characteristics, which includes information on vehicle ownership, the availability of road infrastructure, public transport and other mobility services. Second, it generates trips. Third, a mode split module calculates mode shares using a discrete choice model that accounts for cost, time and accessibility attributes of the different modes. Lastly, transport emissions are estimated based on vehicle load factor and average vehicle emissions depending on the local vehicle fleet composition.

Notes:
1. Macro FUAs are aggregations of FUAs defined by the joint EC-OECD Cities in the World project and identified in the UN DESA World Urbanization Prospect 2018 project.
2.List of the 18 modes included in the model: Walk, Bike, Private motorcycle, Private car, Taxi, PT rail, PT metro, PT Light Rail Transit, PT Bus Rapid Transit, PT bus, Informal bus, Informal three wheelers, Scooter sharing, Bike sharing, Ride sharing, Motorcycle sharing, Car sharing, Taxi-bus.
3. Disaggregation of the city population in 36 age and gender categories based on WorldPop data from the University of Southampton.

The 2021 ITF *Transport Outlook* summarises likely short- and long-term impacts of the Covid-19 pandemic, and describes which opportunities and challenges will present themselves in the recovery. These are outlined in Table 2.

Beyond the opportunities and challenges outlined above, the Covid-19 pandemic has highlighted the need to fully build in a pro-resilience stance in mobility policies and transport services and networks. This focus on resilience implies going beyond single-mode resilience to cross-modal, systemic resilience optimisation. It also implies going beyond a singular focus on robustness (the ability for a system to function despite absorbing a shock) and, even beyond resilience (the ability of a system to recover its function after a shock). It calls for a fully regenerative or "anti-fragile" approach as well, in which the system emerges changed and improved from the shock and is thus stronger and better able to absorb future shocks (Taleb, 2012; Wenzel et al., 2020; Ramezani and Camarinha-Matos, 2020; Derbyshire and Wright, 2014).

Key aspects to consider when developing robust, resilient and regenerative transport policies and systems are diversity (of skills and means), modularity, cohesion and adaptability. Diverse systems handle shock better. They do so by introducing redundancy and slack in systems and by having multiple options for achieving objectives. Modularity refers to the ability to separate and recombine a system's components; it enhances flexibility and allows multiple operation and response options. Modularity is enhanced by both connectivity and system openness. Cohesion and trust allow diverse and modular systems to function with agility. Adaptability is enabled by proactive uncertainty management strategies and scenario-planning exercises. It requires monitoring, threshold-setting, dynamic feedback loops and *ex post* assessment to determine which course of action to adopt in the face of change.

Table 2. Potential urban and peri-urban sustainability challenges and opportunities post-Covid-19

	Potential opportunities	Potential challenges
Short-term impacts	Urban passenger transport • High levels of teleworking, reducing commuting trips • Increased use of active and micromobility • Rapid implementation of active mobility lanes/reallocation of road space • Reduction in car use, congestion, and pollution Non-urban passenger transport • Increased teleworking, reduced business travel trips • Increase in localised tourism due to health concerns	Urban passenger transport • Reduction in public transport and shared mobility ridership due to health concerns and shift to car use Non-urban passenger transport • Higher usage of private vehicles due to health concerns, leading to a reduction in cleaner "shared" modes (bus, rail)
Long-term/structural changes	Urban passenger transport • Increased teleworking, reducing commuting trips and increasing local trips • Focus on local trips and land use may favour land use policy to densify neighbourhood centres • Deployment of permanent active mobility infrastructure and reallocation of road space • Change in public transport funding systems to more sustainable models Non-urban passenger transport • Paradigm shift for businesses reducing business travel trips • Increased localised tourism due to travel behaviour changes All sectors • Accelerated transition to cleaner technologies in response to policy signals and investments spurred by stimulus packages • Greater political will and opportunity to foster greener technologies and operations	Urban passenger transport • Increase in car use due to health concerns • Reduction of public transport ridership due to change in habits or sanitary concerns • Lack of funds in private and public sector for research in sustainable fuels • Lack of funds to finance public transport. • Stimulus packages that support a return to the status quo • Unmanaged urban sprawl if people move out of cities due to teleworking Non-urban passenger transport • Higher usage of private vehicles and reduced usage of bus and rail modes due to changes in preferences All sectors • Delays in adoption of cleaner technologies due to lack of investment by private and public sectors (e.g. slower renewal of fleets and deployment of new infrastructure) • Stimulus packages that support a return to the status quo

Note: Short-term impacts are based on observed changes in travel behaviour during the pandemic that hurt or hinder sustainability. Most long-term and structural opportunities rely on well-designed recovery policies, while challenges add constraints to future sustainability.

Source: Adapted from ITF (2021).

Looking ahead: Urban mobility outlook to 2050

Demand for urban mobility depends on a number of factors. The most significant are population size, economic activity and land use. Population growth increases total mobility volumes (measured in passenger-kilometres), while travel per capita tends to grow as incomes increase (Rodrigue et al., 2009). How this travel is undertaken – by which transport mode and to which destinations – will influence total travel volumes and their associated emissions and impacts.

The actual distances travelled are largely influenced by land-use patterns and the density of mixed developments. Cities where jobs are located close to residences and commercial areas will result in fewer kilometres travelled than those with sprawling, segregated patterns of development. More transport activity, therefore, is not an indicator of greater well-being. Rather, accessibility – which considers individual needs – locations of opportunities, and the transport services between the two are what influence quality of life. Higher transport volumes are often due to limited accessibility, which results in longer trip distances and higher costs in terms of both time and budget. It also increases CO_2 emissions, air pollution and crash risks.

A growing world population combined with fast-paced urbanisation will inevitably increase transport demand in cities. By 2050 almost seven billion people will live in cities, approximately the entire world population of 2015 (United Nations, 2018). Cities in developing countries will grow the most over the next thirty years. The urban population of sub-Saharan Africa will increase at the fastest pace, almost tripling between 2020 and 2050. In Asia, the urban population will nearly double in the same period. Authorities in these regions will be hard-pressed to meet this growing demand in sustainable ways. Already, urban trips far outnumber all other passenger trips worldwide, and urban travel is set to grow significantly in step with urban population growth and wealth. Under current policies, ITF estimates a 163% global increase in urban travel activity by 2050 compared to 2015 levels.

Individual motorised transport represents a significant share of all trips and the majority of passenger kilometres travelled in most cities. In 2015, more than a third of passenger trips were made by private vehicles, 2.5 times those made with public transport. These trips accounted for more than half of all urban passenger-kilometres in that year. They support widespread but unevenly distributed access opportunities for people. However, adverse health effects, social inequalities, fossil fuel dependence and congestion caused by excessive car use entail high economic, environmental and social costs. Projections see the global private passenger vehicle fleet growing by more than 30% between 2020 and 2030, reaching 1.4 billion vehicles by 2050 (IEA, 2020). In 2015, private vehicle use generated three-fourths of all urban passenger transport-related GHG emissions worldwide. This is mostly the result of continued growth in both private vehicle ownership and increasing average vehicle size. The United States and Canada taken together as one region have 733 vehicles per 1 000 inhabitants and the highest share of emissions from private car use in international comparison (OICA, 2020). The growing demand for larger sports utility vehicles (SUVs) is further challenging emission reduction. Nearly half of all cars sold in the United States in 2018 were SUVs, and worldwide the share of new SUVs has doubled compared to a decade ago (IEA, 2019).

The 2021 ITF *Transport Outlook* presents three policy scenarios – *Recover, Reshape,* and *Reshape+* – which assess what urban transport could look like globally, under varying policies.

Recover: A return to "normal"

In the Recover scenario, the world reverts back to a pre-Covid "normal" as governments primarily reinforce established economic activities during recovery. Any impacts on urban travel observed during 2020 gradually disappear by 2030. This includes policies that reverse trends in increased private car use and reduction in public transport ridership, for example, with a return to pre-pandemic levels. However, there is no improvement beyond that. Changes in behaviour, such as greater shifts to active mobility that have lowered CO_2 emissions, also revert back to pre-pandemic levels by 2030. Policies to mitigate CO_2 emissions (that are now in place or were about to be implemented) are honoured. But further efforts beyond carbon pricing are not made. Some cities and suburbs densify while others sprawl. Neighbourhoods around public transport hubs experience a modest increase in density and diversity of use. In some city streets, priority continues to shift from sole car use to active mobility and public transport through bike and pedestrian infrastructure, speed limits, and public transport priority measures. Nonetheless, this remains far from the norm. Car use is also increasingly restricted in some cities through urban vehicle restriction schemes, parking pricing and regulations, and road pricing mechanisms. Implementation of the measures described above is not widespread. At the same time, low-emission vehicles are encouraged through incentives and infrastructure investment in a few cities. Car sharing, carpooling and shared transport modes are encouraged as alternatives to private cars. Public transport receives moderate investment. There is, on average, little change to rail corridors. Bus and paratransit improves slightly in service. Some cities increase their service network, but do not integrate with other modes efficiently.

Reshape: A change of paradigm

The Reshape scenario simulates a world where impacts of Covid-19 on urban travel gradually disappear by 2030 as well, similar to Recover. However, policy makers adopt an ambitious decarbonisation policy portfolio to prioritise reducing CO_2 emissions, in line with the shift towards accessibility. Carbon pricing increases from the Recover scenario across all regions and is applied to all modes. Cities maintain the same level of density or increase in both city centres and suburbs. Transit oriented development is more pronounced than in Recover, increasing density and diversity around transport hubs. Space re-allocation on city streets more strongly deprioritises private cars. Speed limits are reduced further, at least some of the public transport networks in all cities are prioritised through lanes or signal priority measures; and bicycle and pedestrian infrastructure expands and improves dramatically in more cities. Urban vehicle restriction schemes, road and parking pricing and regulations reduce car use considerably more than in Recover. Incentives for carpooling, car sharing and ride sharing have a more noticeable impact on average load factors and the availability of shared alternatives to private car. Incentives and investment in infrastructure for electric and low-emission vehicles increase and have a marked impact on average CO_2 emissions in some cities. Public transport networks improve in service and reach, and offer a highly integrated service with seamless transfers with other modes through Mobility as a Service (MaaS) applications. Paratransit services are also gradually regulated and integrated with formal public transport or shared mobility systems, which results in a cleaner fleet.

Reshape+: Reinforcing Reshape

In Reshape+, the impacts of Covid-19 on transport are drawn on further to advance the transformation that is set out in the Reshape scenario. In most ways the scenario remains the same as Reshape but with some key changes. Reshape+ also assumes that decarbonising policies are implemented to ensure the transport trends observed during Covid-19 that challenge decarbonisation revert to previous patterns by 2030. However, it seizes opportunities for decarbonisation that emerged during the pandemic. These trends include teleworking and active mobility. Teleworking, though exogenous to transport policy, is assumed to increase, allowing a greater portion of the population to reduce work-based trips more frequently. To further facilitate positive attitudes toward public transport, and to combat any potential impact from people moving away from city centres, Reshape+ has greater levels of transit-oriented development. Bicycle and pedestrian infrastructure is available to a higher degree, aided by the temporary measures initiated during the pandemic. Finally, governments use stimulus packages to increase low-emission vehicle incentives, for shared and private fleets. The benefits of Reshape are moved forward, allowing the cities to reach decarbonisation sooner and with more certainty.

Total urban passenger demand is projected to grow by 59% to 2030 and 163% by 2050 from the base year 2015 under the Recover scenario. The increase in urban travel demand would be limited to 116% under Reshape and 104% under Reshape+, if even more ambitious policies were put in place between 2015 and 2050, A combination of shorter trips due to land-use changes and fewer work trips as a result of more teleworking are behind this result. These changes increase accessibility, well-being and economic growth despite lower overall transport volumes. Reshape+ in particular assumes the most ambitious land-use changes and rates of telework. Some work trips are replaced by an increase in local non-work trips, but in a well-managed land use scenario, they are assumed to be shorter in nature, and are expected to have a net reduction on urban kilometres travelled.

Table 3 summarises the key features and assumptions behind all three scenarios.

Table 3. Scenario specifications for urban passenger transport

Measure/Exogenous factor	Description	Recover	Reshape	Reshape+
Economic instruments				
Carbon pricing	Pricing of carbon-based fuels based on the emissions they produce.	Carbon pricing varies across regions: USD 150 to USD 250 per tonne of CO_2 in 2050.	Carbon pricing varies across regions: USD 300 to USD 500 per tonne of CO_2 in 2050.	
Road pricing	Charges applied to motorised vehicles for the use of road infrastructure.	0% to 7.5% increase of non-energy related car use costs by 2050, half for motorcycles.	2.5% to 25% increase of non-energy-related car use costs by 2050, half for motorcycles.	
Parking pricing and restrictions	Regulations to control the availability and price of parking spaces for motorised vehicles.	5% to 50% of a city area subject to parking constraints, and 0% to 60% increase in parking prices by 2050.	7% to 75% of a city area subject to parking constraints and 20% to 150% increase in parking prices by 2050.	
Enhancement of Infrastructure				
Land-use planning	Densification of cities.	Density variation of -10% to +20% for the city centre of urban areas over 300 000 inhabitants. Density variation of -10% to +10% for cities under 300 000 inhabitants and for suburbs of urban areas over 300 000 inhabitants.	Density variation of 0% to +40% for the city centre of urban areas over 300 000 inhabitants. Density variation of 0% to +20% for cities under 300 000 inhabitants and for suburbs of urban areas over 300 000 inhabitants.	
Transit-Oriented Development (TOD)	Increase in mixed-use development in neighbourhoods around public transport hubs.	Increases the land-use diversity mix and increases accessibility to public transit by 5% by 2050.	Increases the land-use diversity mix and increases accessibility to public transit by 7.5% by 2050.	Increases the land-use diversity mix and increases accessibility to public transit by 10% by 2050.

<table>
<tr><th>Measure/Exogenous factor</th><th>Description</th><th>Recover</th><th>Reshape</th><th>Reshape+</th></tr>
<tr><td>Public transport priority measures and express lanes</td><td>Prioritising circulation of public transport vehicles in traffic through signal priority or express lanes.</td><td>0% to 40% of bus, light-rail transit and bus rapid transit network prioritised by 2050.</td><td colspan="2">10% to 60% of surface public transport network prioritised by 2050.</td></tr>
<tr><td>Public transport service improvements</td><td>Improvements to public transport service frequency and capacity.</td><td>-10% to +10% service improvement for rail or corridor-based public transport systems resulting in a -1% to +1% speed variation by 2050. 10% to 30% service improvement for bus and paratransit transport systems resulting in a 0.25% to 0.7% speed variation by 2050.</td><td colspan="2">10% to 15% service improvement for rail or corridor-based public transport systems resulting in a 1% to 1.5% speed variation by 2050. 20% to 50% service improvement for bus and informal public transport systems resulting in a 0.5% to 1.25% speed variation by 2050.</td></tr>
<tr><td>Public transport infrastructure improvements</td><td>Improvements to public transport network density and size.</td><td>0% to 100% growth increase for the public transport network by 2050.</td><td colspan="2">0% to 200% growth increase for the public transport network by 2050.</td></tr>
<tr><td>Integrated public transport ticketing</td><td>Integration of public transport ticketing systems.</td><td>1.5% to 4.5% reduction of a public transport ticket cost, and 2.5% to 7.5% reduction of public transport monthly subscription cost by 2050.</td><td colspan="2">1.5% to 7.5% reduction of a public transport ticket cost, and 2.5% to 12.5% of public transport monthly subscription cost by 2050.</td></tr>
<tr><td>Bike and pedestrian infrastructure improvements</td><td>Increase in dedicated infrastructure for active mobility.</td><td>20% to 300% increase in road space available to active modes by 2050 and a simultaneous increase in the speed of active modes, including micromobility.</td><td>40% to 500% increase in road space available to active modes by 2050 and a simultaneous increase in the speed of active modes, including micromobility.</td><td>50% to 600% increase in road space available to active modes by 2050 and a simultaneous increase in the speed of active modes, including micromobility.</td></tr>
<tr><td>Speed limitations</td><td>Traffic calming measure to reduce speed and dominance of motor vehicles through low-speed zones or infrastructure.</td><td>2% to 30% reduction of speed on main roads, by 2050.</td><td colspan="2">5% to 50% reduction of speed on main roads, by 2050.</td></tr>
<tr><th colspan="5">Regulatory instruments</th></tr>
<tr><td>Urban vehicle restriction scheme</td><td>Car restriction policies in certain areas and during certain times to limit congestion. Typically applied in the city centre.</td><td>0% to 17.5% reduction of car ownership by 2050. Reduction of the car and car sharing speeds while increasing</td><td colspan="2">3.5% to 25% reduction of car ownership by 2050. Reduction of the car and car sharing speeds while increasing the car and motorcycle access time.</td></tr>
</table>

Measure/Exogenous factor	Description	Recover	Reshape	Reshape+
		the car and motorcycle access time.		
Low-emission vehicle incentives and infrastructure investment	Incentives for the purchase and use of alternative fuel vehicles.	Decreases average vehicle-kilometres travelled with diesel, gasoline and methane fuels between 0% and 4% by 2050.	Decreases average vehicle-kilometres travelled with diesel, gasoline and methane fuels between 0% and 36% by 2050.	Decreases average vehicle-kilometres travelled with diesel, gasoline and methane fuels between 0% and 45% by 2050.
Stimulation of innovation and development				
Electric/alternative fuel vehicle penetration	Degree of uptake of electric/alternative vehicles in an urban vehicle fleet.	Follows the IEA NPS Scenario.	Follows the IEA SDS Scenario.	
Car-sharing incentives	Incentives to encourage car rental schemes where members have access to a pool of cars as needed, lowering car ownership.	0% to 15% increase in shared car availability per capita, and 0% to 40% increase in shared motorcycle availability per capita, by 2050.	5% to 30% increase in shared car availability per capita, and 10% to 60% increase in shared motorcycle availability per capita, by 2050.	
Carpooling policies	Carpooling policies encourage consolidating private vehicle trips with similar origins and destinations.	3.5% to 8.3% increase in average load factor by 2050.	7.6% to 16.7% increase in average load factor by 2050.	
Ride-sharing/shared mobility	Increased ridership in non-urban road transport (car and bus).	25% to 200% increase of ride-sharing vehicles per capita growth by 2050. Load factor evolution from -50% to +25% by 2050.	25% to 300% increase of ride-sharing vehicles per capita growth by 2050. Load factor increase from 0% to 100% by 2050.	
Mobility as a Service (MaaS) and multimodal travel services	Improved integration between public transport and shared mobility (app integration as well as physical infrastructure, ticketing and schedule integration). Increase in availability and load factors of shared mobility.	1.7% to 10% reduction of a public transport ticket cost, and 1.0% to 6.0% reduction of shared mobility cost by 2050. Increase in the number of shared mobility vehicles and stations.	3.3% to 20% reduction of a public transport ticket cost, and 2.0% to 12.0% reduction of shared mobility cost by 2050. Significant increase in the number of shared mobility vehicles and stations.	
Exogenous factors				
Autonomous vehicles*	Introduction of vehicles with level 5 autonomous capabilities.	The percentage of autonomous vehicles in use varies across regions: for car 0% to 3%, for bus 0% to 1.5%, for shared vehicles 0 to 6%.		

Measure/Exogenous factor	Description	Recover	Reshape	Reshape+
Teleworking	Reduces business and commuting trips, while increasing short non-work trips.	2.5% to 20% of the active population could telework by 2050.	3.5% to 30% of the active population could telework by 2050.	5% to 40% of the active population could telework by 2050.

*Autonomous vehicles are considered but are not a primary factor in any of the scenarios. All scenarios assume a constant level of introduction of vehicles with Level 5 autonomy. The ITF Transport Outlook 2019 focussed more specifically on transport disruptions, including autonomous vehicles, and assessed related scenarios.

Note: Range of values reflects the varying degrees of implementation of policy measures across the different world regions in each scenario.

More than half of global urban passenger-kilometres travelled in 2015 were made with private vehicles. By 2050, however, the more ambitious policies simulated in the Reshape+ scenario could limit demand for private vehicle passenger-kilometres to one-third of 2050 global totals (Figure 4). Policies to limit private vehicle use and decrease car ownership achieve the most pronounced mode shift away from private vehicles. Car restriction schemes, pricing mechanisms for parking, road use and carbon, and the reallocation of road space away from cars all decrease the relative attractiveness of private car use vis-à-vis active mobility, public transport and shared mobility. Changes in land use and transit-oriented development (TOD) allow for shorter travel distances and may determine whether citizens choose to drive or not. Private vehicles are more attractive to those with inferior alternatives and those travelling longer distances, or linking several destinations.

In the Reshape+ scenario, integrated land-use planning and transit-oriented development bring particularly positive results in shifting shorter trips away from private cars. For distances between one and ten kilometres, private vehicle shares are 7 to 9 percentage points lower in 2050 under the Reshape+ scenario than under the Recover scenario (Figure 5). Private vehicle use is replaced mainly by forms of active and micromobility for shorter distances and shared transport for longer trips.

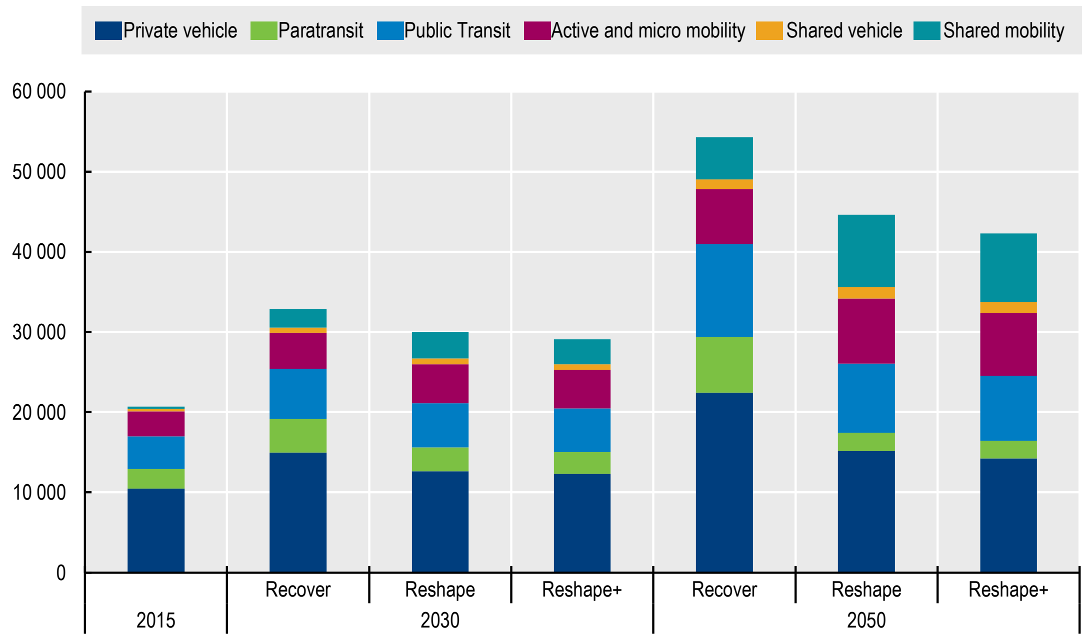
Active modes, shared mobility and public transport gain ground in ambitious scenarios. Trips by private car primarily shift to taxi, ride sharing and taxi-bus as well as shared vehicle ownership schemes for longer distances. Shared mobility grows from 1% of passenger-kilometres in 2015 to 10% in 2050 in the Recover scenario. Shared vehicles maintain a 2% share between 2015 and 2050. Under Reshape and Reshape+, shared vehicles account for 3% of passenger-kilometres, and shared mobility accounts for one-fifth of passenger-kilometres by 2050. *Public transport use grows by 184% by 2050 in Recover.* Its share of total demand remains steady in 2050, as more of the shorter trips use active modes, especially with more ambitious decarbonisation policies in place. Walking, cycling and micromobility make up 18% of total passenger-kilometres by 2050 in both Reshape and Reshape+, growing from 15% in 2015.

Paratransit will likely be absorbed by shared mobility and public transport. Paratransit is informal collective transport. It dominates urban mobility in many developing countries. Under the Recover scenario, the share of paratransit grows to 13% of total passenger-kilometres by 2050. Yet in Reshape and Reshape+ it plummets to only 5%, largely due to the formalisation of paratransit options in developing nations.

Asia remains the highest generator of urban transport demand. Total urban passenger transport demand varies considerably by region, but is projected to grow in all regions under all policy scenarios (Figure 6). Asia contributed 40% of transport activity in 2015, the largest share of all regions. Driven by strong economic growth, rapid urbanisation and fast motorisation of China and, to a lesser extent, India, total urban passenger activity triples by 2050 in the Recover scenario. Policies in line with the Reshape scenario would cut 17% of demand compared to Recover in 2050 and Reshape+, 21%.

Figure 4. Demand for urban passenger transport, by mode

Billion passenger-kilometres



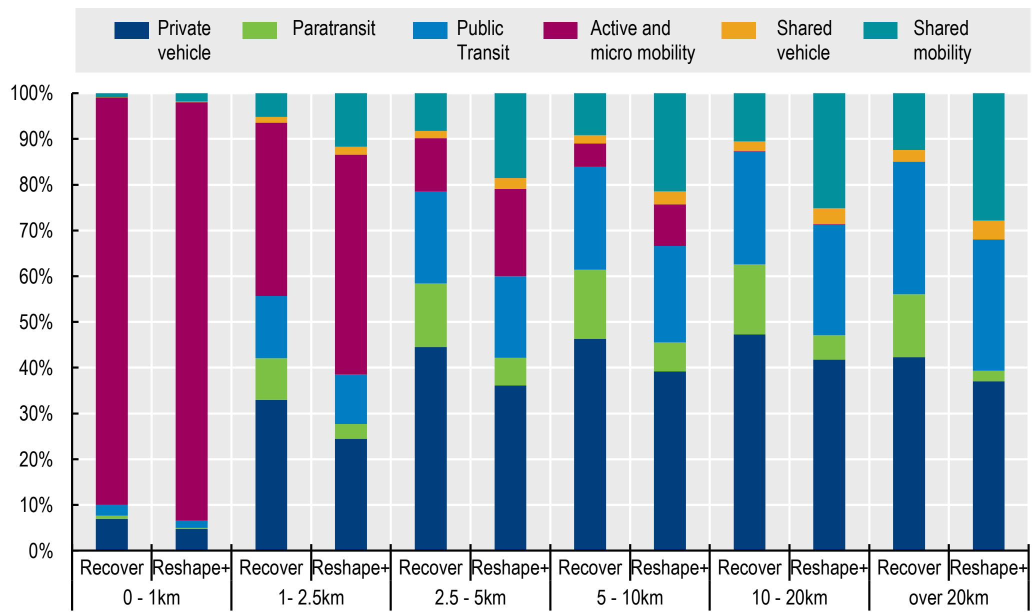
Note: Note: Active and micromobility includes walking, biking, scooter sharing, and bike sharing. Public transport includes PT rail, metro, bus, LRT, and BRT. Paratransit includes informal buses and PT three-wheeler. Shared vehicle includes motorcycle and car sharing. Private Vehicle includes motorcycles and cars. Shared mobility includes taxis, ride sharing, and taxi buses.

Significant scope exists to restrain urban mobility growth in North America. The United States and Canada were responsible for 20% of the global urban passenger-kilometres in 2015, due to low density urban developments and longer travel distances. Cities in the region are often decentralised, requiring long commutes. Reshape policies would limit the growth of travel demand in cities to 13% above 2015 levels in 2050. Under Reshape+ policies, demand growth could be frozen at close to 2015 levels. The region comprising the European Economic Area (EEA) + Turkey as well as the Middle East and North Africa (MENA) region also show considerable potential to limit demand growth under higher ambition policies. Compared to 2015 totals, 2050 demand growth could be 19% and 30% under Reshape policies, but 8% and 20% with a Reshape+ agenda, respectively.

Population growth and economic development drive urban mobility demand in other regions. The highest relative growth in transport activity is projected for Latin America and the Caribbean (LAC) and Sub-Saharan Africa (SSA) driven by high economic growth in LAC and significant urban population growth in SSA. Under current policies, LAC's urban transport activity is estimated to be 3.5 times higher by 2050 than in 2015, and 6.2 times higher in SSA. Mitigation potential is more limited in the region due to financial constraints, urbanisation patterns, and rising living standards. However, Reshape+ policies would enable these regions to achieve an 18% to 25% reduction in 2050 compared to a Recover scenario. A shift to sustainable options could allow these regions to leapfrog developed countries that are locked into unsustainable transport systems based on private vehicle ownership. Under Reshape+ LAC could see growth limited to 2.7 times 2015 values by 2050, and SSA 4.9 times.

Figure 5. Average urban passenger trip mode shares by distance, in 2050

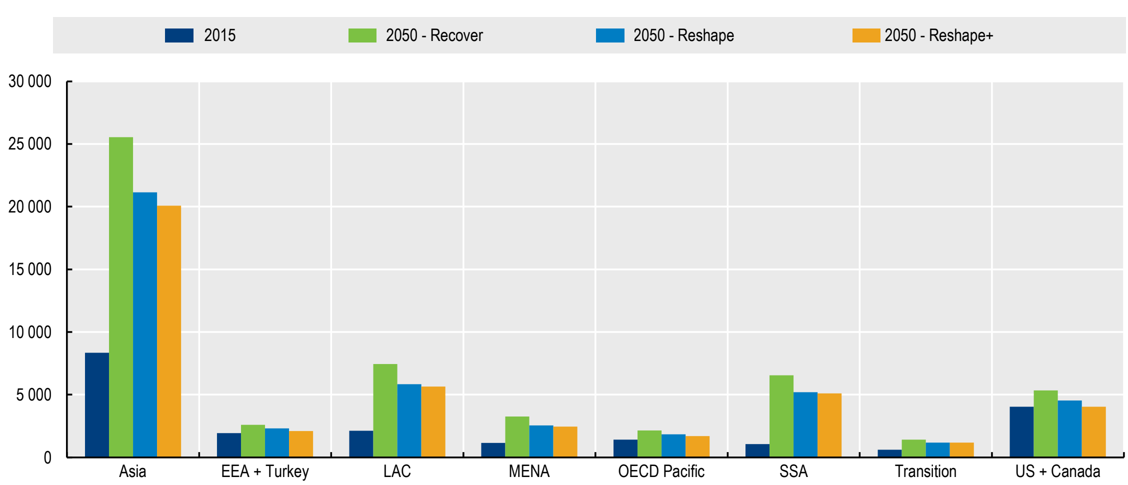
Mode share by trips



Note: *Reshape* results in very similar trip-based mode shares as *Reshape+*, therefore it is not pictured separately. Active and micromobility includes walking, biking, scooter sharing, and bike sharing. Public transport includes PT rail, metro, bus, LRT, and BRT. Paratransit includes informal buses and PT three-wheeler. Shared vehicle includes motorcycle and car sharing. Private Vehicle includes motorcycles and cars. Shared mobility includes taxis, ride sharing, and taxi buses.

Figure 6. Demand for urban passenger transport, by region

Billion passenger-kilometres

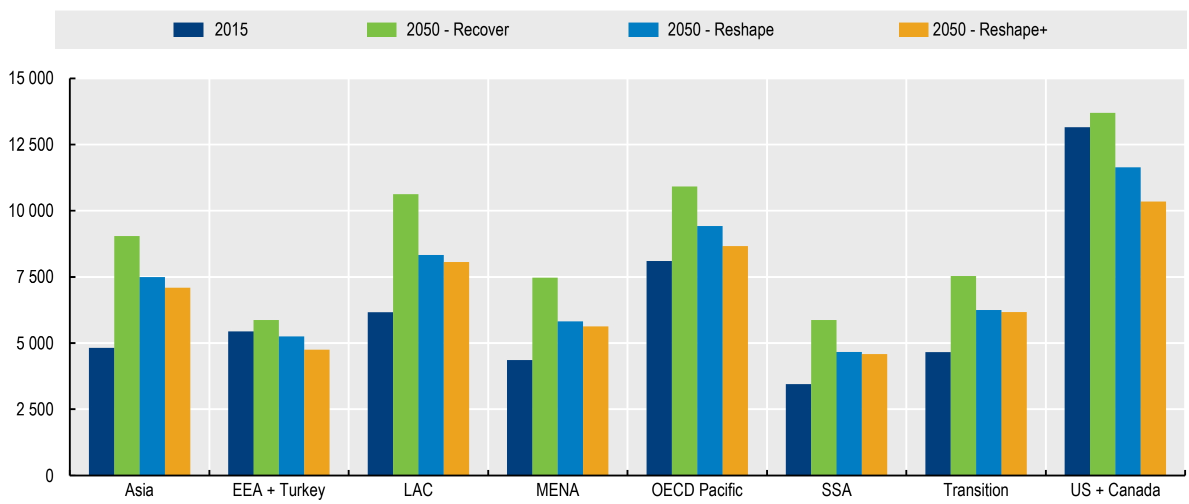


Note: EEA refers to the European Economic Area. LAC refers to Latin America and the Caribbean. MENA refers to the Middle East and North African countries. OECD Pacific countries include Australia, Japan, New Zealand and South Korea. SSA refers to sub-Saharan Africa. Transition economies include countries that were part of the Former Soviet Union and non-EU south-eastern European countries.

Per capita transport demand is highest in the United States and Canada. In 2015, the United States and Canada generated 2.7 times more passenger-kilometres per person on average than individuals in Asia, the region with the largest total urban passenger demand (Figure 7). Urban mobility per inhabitant in the OECD Pacific region (Australia, Japan, Korea and New Zealand) is also significantly higher than in Asia, by a factor of 1.7. Compared to Sub-Saharan Africa (SSA), the region with the lowest urban travel per inhabitant, the average city-dweller in the United States and Canada generates 3.8 times as much demand, and individual travel in the OECD Pacific region is 2.3 times higher. This gap will narrow by 2050, but even then the United States and Canada still generate 2.3 times the per capita travel demand of SSA, and the OECD Pacific region 1.9 times. The United States and Canada reduce per capita demand by 21% by 2050 under Reshape+, compared to 2015. The region comprising the European Economic Area (EEA) + Turkey achieves the second highest reduction of 13%. By 2050, most other regions generate more travel activity per capita even under Reshape+ compared with 2015 levels.

Figure 7. Per capita demand for urban passenger transport, by region

Passenger-kilometres per capita



Note: EEA refers to the European Economic Area. LAC refers to Latin America and the Caribbean. MENA refers to the Middle East and North African countries. OECD Pacific countries include Australia, Japan, New Zealand and South Korea. SSA refers to sub-Saharan Africa. Transition economies include countries that were part of the Former Soviet Union and non-EU south-eastern European countries.

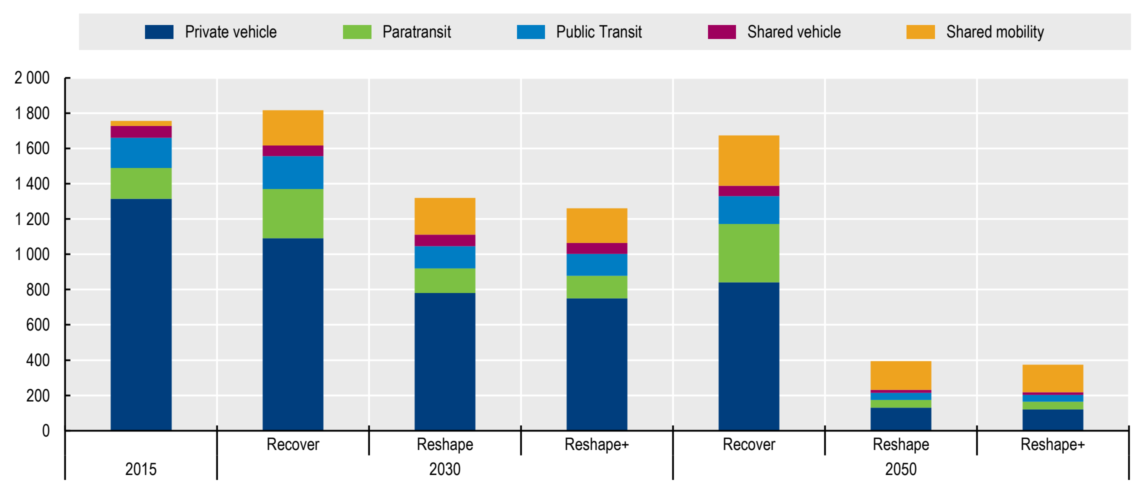
Increases in load factors and fuel efficiency result in lower emissions. In addition to motorised passenger demand, emissions depend on how many people share a vehicle trip, known as the vehicle load factor, and the fuel efficiency of the vehicle. The preceding section describes the projected growth in demand from 2015 to 2050. In Recover, motorised travel holds 87% of the passenger-kilometre share by 2050, while in Reshape and Reshape+ it is responsible for 82% of travel thanks to a shift to active modes. Figure 8 shows the CO_2 emissions generated by mode for each scenario. In Recover, vehicle efficiency improves so that on average, vehicles emit 57% less CO_2 in 2050 compared to 2015 over the same distance. In Reshape and Reshape+, emissions per vehicle-kilometre are 86% lower in 2050 than in 2015. In addition, measures to increase vehicle load factors by shifting to mass and well-integrated shared transport and carpooling incentives mean that average vehicle load factors are 22% higher in 2050 than in 2015 in the Recover scenario, and 28% to 29% higher in the more ambitious scenarios. Therefore, CO_2 emissions generated per passenger-kilometre drop by 65% by 2050 in Recover and by 89% in Reshape and Reshape+.

Emissions from private vehicles in cities can be more than halved. In 2015, emissions from private vehicle use made up three-quarters of urban passenger emissions. The share drops to 50% in Recover, primarily because of technological improvements and mode shift. In Reshape and Reshape+ they drop 56% and 57% by 2050 thanks to more pronounced mode shift, higher load factors and more ambitious expectations of new technology penetration in the vehicle fleet.

Self-driving cars and electric vehicles are no panacea for curbing emissions. Future transport emissions will not fall to required levels through automation and electrification alone (Fulton et al., 2017). Automated and electrified cars are only a part of the solution, not the solution, because of implementation challenges and the externalities they create. For example, the fast-growing share of electric vehicles in some developed and fast-growing economies do not address the negative externalities from congestion, regardless of their energy efficiency. Also, electric vehicles reduce local emissions and can improve air quality, but they will only contribute to decarbonisation if powered with clean electricity. Automated cars bring the risk of increasing congestion in cities, among others by facilitating empty trips. Because of their limitations, technical improvements like automation and electrification will only bring about sustainable wins in transport decarbonisation when combined with other measures in a holistic approach. This includes policies aiming to reduce demand and shifting to sustainable modes.

Figure 8. CO_2 emissions from urban passenger transport, by mode

Million tonnes CO_2 direct emissions (tank to wheel)



Note: Active and micromobility includes walking, biking, scooter sharing, and bike sharing. Public transport includes PT rail, metro, bus, LRT, and BRT. Paratransit includes informal buses and PT three-wheelers. Shared vehicle includes motorcycle and car sharing. Private Vehicle includes motorcycles and cars. Shared mobility includes taxis, ride sharing, and taxi-buses.

New shared mobility services have great potential to reduce the need for private cars. In combination with alternative fuels, such innovative services could achieve significant emission reductions. A lot of uncertainty surrounds the widespread adoption of shared mobility, however (Fulton et al., 2017). It will require strong supportive policies and financial incentives to ensure that services with higher load factors are succeeding, rather than services that create additional traffic (ITF, 2020; ITF, 2016). Shared mobility services will include non-car-based modes (e.g. “agile mobility” services based on electrified two- and three-wheelers) that act as a complement to existing public transport services for the last kilometre (ITF, 2019b).

Well-integrated shared mobility is much less emitting. Most motorised modes reduce emissions by 2050 compared to 2015, in all scenarios. Shared mobility and paratransit are exceptions. The market penetration of shared mobility is very low in 2015, and as it gains mode share, its emissions appear to grow. With only minimal integration and management of shared mobility services in the Recover scenario, shared mobility emissions increase tenfold between 2015 and 2050. However, in scenarios where shared mobility is well managed and fully integrated into the transport system, its emissions grow only little more than half as much (57% and 55% respectively for the Reshape and Reshape+ scenarios compared to the Recover scenario). Paratransit under a Recover scenario also emits more due to demand growth, but fall under the more ambitious policies as these informal services are integrated into the official networks.

Shared vehicles and shared mobility allow faster adoption of clean technologies. Both have higher utilisation than a typical private car and vehicles thus need to be replaced more often. In a well-integrated system, shared mobility fills gaps in the public transport network and augments the overall offer. Swaying users to give up private cars for shared mobility requires integrated fares, routing and schedules with existing public transport via mobile phone applications. The targeted reconfiguration of urban space to make transfers seamless will also help considerably. Shared mobility's potential to offer a sustainable travel alternative depends on how well it is integrated with public transport, acting as a complement to, rather than replacement of, public transport. A poorly managed system that leads to the substitution of public transport could easily have the reverse effect on emissions, as seen by the higher 2050 emissions by shared mobility in Recover.

The 2021 ITF *Transport Outlook* makes several recommendations regarding how policy can support long-term urban sustainability goals. These include the following:

Empower cities to decarbonise, to boost accessibility and well-being. This includes setting clear, specific and ambitious objectives at the national level. At the local level, authorities need to develop and implement measures that are aligned with strong decarbonisation outcomes. Data collection and monitoring of progress is essential. Decarbonisation policies need to shift the focus from maximising individuals' mobility to increasing access to opportunities for all people to meet their needs.

Shift transport funding in cities from roads to public and shared transport. Overall transport investment should be re-prioritised, with a larger portion of it directed to public transport improvements rather than investments that primarily serve private vehicles. With the additional financial constraints of the Covid-19 crisis, prioritising investment in line with public policy outcomes is essential. This means investing in public transport and supporting emerging shared mobility where it serves as an important alternative to private vehicle use.

Increase space and support for active mobility and micromobility. During Covid-19, cities have essentially piloted new space reallocation models, deprioritising cars on streets and supporting safer, more convenient active mobility and micromobility. Cities should seize the opportunity to make these interventions permanent and fast-track plans to expand active mobility networks.

Integrate land use and transport planning. Land-use policies that focus on mixed use, dense, transit-oriented development are vital to help manage the growth of cities world-wide. Sustainable urban development shortens the distances residents need to travel to access opportunities, supports active and micromobility for local trips, and makes public transport a convenient choice for longer trips.

Improve the quality of public transport services. Improving public transport makes a city's transport system more equitable by providing better service to those who depend on it. Improvements would also make public transport more competitive in comparison to private vehicle use, which is important to shift people from using private modes to more sustainable alternatives. Service frequency, reliability, schedule integration between services, and infrastructure improvements all enhance the level of service.

Encourage cleaner private, shared and public vehicle fleets. Even in the most ambitious scenario, by 2050 at least one-third of urban travel will still be made by private vehicles. Reducing emissions from these trips requires technology improvements that increase fuel efficiency. Making new fuel technologies affordable will be essential for decarbonising passenger activities, especially in areas where inhabitants do not have options other than using private vehicles.

Foster innovation and collaborate with new mobility operators. Shared mobility can offer substantial environmental and social benefits if well managed and act as a complement to existing forms of public transport. It should improve, not erode, the viability of public transport networks. By supporting shared mobility services, cities can shape positive gains in terms of access to opportunities for all. Authorities and operators should work together to ensure affordable services, especially in areas where public transport service is lacking. Emerging shared mobility services might be considered for subsidies where shared mobility could enhance access to opportunities by complementing public transport as first- and last-mile solutions. This combined offer can be co-ordinated through a Mobility as a Service platform, but requires collaboration among all parties.

Combine transport decarbonisation and resilience measures. Promoting the adaptation of transport services and infrastructure is essential to absorb future shocks. Authorities should look at resilience in the division of a system’s functions; in its operations; in its capacity to recover; and in stakeholder engagement for resilience planning. Higher ambition decarbonisation policies can increase resilience by decreasing the overdependence on private vehicles and creating a multimodal transport system.

The emerging mobility service landscape

How we move: New layers, more choices, more digital

The arrival of information and communication technologies and the spread of practically ubiquitous smartphones are profoundly disrupting the urban mobility landscape. These developments have enabled new service delivery models that have seen rapid uptake in many markets. Strictly speaking, many of these emerging mobility services, described as "new" or "innovative", have existed in some form for decades. However, the arrival of the smartphone has greatly impacted service delivery models, given that users can connect with transport operators directly or via online platforms through mobile applications allowing easier planning and payments. Moreover, these services build on multiple existing layers of infrastructure, institutions, regulations and practices. While they are new, they are also deeply embedded in the present and historical context.

This section provides an overview of the existing offer of mobility services, with a particular focus on the current status and future potential of new mobility services that are entering or expanding in the market. It first reviews the kinds of mobility services and mode types that are available globally, and then describes emerging tensions that result from the arrival of new mobility services.

Mobility services: A diverse and changing landscape

The evolving urban mobility landscape comprises a growing diversity of service delivery models and consumer choices (Table 4). While this diversity is considerable, in practice only a few transport service models dominate. Individual transport by foot, bicycle, motorised two-wheeler or car dominates overall travel activity in most metropolitan regions around the world (see Figure 2). Collective public and informal transport account for the vast bulk of travel using transport services across the globe. Nonetheless, emerging mobility services have proved tremendously popular and though their future uptake trajectory and final potential are still unknown, they are likely to have a lasting effect.

Emerging mobility services have several common features, the principal ones being that most are digitally enabled and some are shared. The digital layer allows people to efficiently connect to vehicles and services through one- or two-sided platforms. Another defining feature is that most enable the shared use of vehicles and transport assets. Sharing creates value by transforming underused or unused assets owned by individuals or firms into productive resources (Einav, Farronato and Levin, 2016)(Santos, 2018). Sharing of transport assets is not new – public transport and many forms of classic informal mobility are built on shared access to and use of transport assets such as mini-buses, buses, the Underground, trams and trains. What is new is the digitally enabled and near real-time access to information about available capacity and the shared vehicles themselves. Such services encompass *sequential* sharing of the same vehicle as well as *simultaneous* sharing of a single vehicle. Shared vehicles may be motorised or not. These and other differences matter to many public authorities as they help to understand the way in which these services contribute to overall welfare and align with public policy objectives relating to equity, sustainability, health and improved access.

Table 4. Urban mobility services

Collective services		Train
		Tram
		Bus
		On demand
Individual services	Active	Bicycle sharing – station-based
		Bicycle sharing – free-floating
		E-bicycle sharing – station-based
		E-bicycle sharing – free-floating
		Bicycle/e-bicycle leasing or renting
	Non-Active	Taxi
		Ride-sourcing (commercial or peer-to-peer car)
		Ride-sourcing (moped/motorcycle)
		Car sharing – station-based
		Car sharing – free-floating (commercial, non-profit) peer-to-peer)
		Motor scooter sharing
		e-push scooter sharing
Personal goods delivery		Cargo bike sharing
		Shop/food delivery services
Informal services	Active	Bicycle/tricycle
		Electric bicycle/tricycle
	Non-active	Motorised two- or three-wheeler
		Motorised
		Car-based
		Minivan/Minibus based

Established incumbents and emerging mobility services share the same urban mobility landscape. In some cases they may compete for the same clients and in others they may complement each other. Some have established and mature regulatory frameworks, while others do not. Understanding of the welfare impacts and burdens imposed by these services is not even and is evolving regarding the impacts linked to new services. Finally, the mix of different business models – and the fact that some involve public intervention and others do not (yet) – and the uncertainty about the viability of some of these clouds understanding of how the market may evolve over time. These asymmetries and uncertainties matter not only when thinking about how to regulate each individual service, but also, and more fundamentally, when thinking about what overarching principles and mechanisms should guide regulation of the urban mobility ecosystem.

Supply-driven long-distance transport services

Supply-driven long-distance transport services are produced according to a predefined schedule and route regardless of the actual demand, where the theoretical chance of services running without customers exists. The customer for this type of service takes on the passive role of a passenger. The category includes international-, domestic intercity- and night-train services as well as coach lines. These services interface with many urban transport services, and their stations and stops serve as key transport nodes in many urban areas concentrating interchange activities and flows.

Who is involved?

In many countries and regions, long-distance railway services are dominated by established national railway organisations with somewhat monopolist positions. That fact leads to controversy over these systems' governance structures when the perspective of fair competition is considered. Increasingly, private new entrant train service operators compete with national railway organisations on lucrative lines, often forming somewhat isolated city-pair connections. In some countries, intercity rail operators are organised as tendered rail franchises (e.g. in the United Kingdom) or operate in an entirely private sector market (e.g. in Japan).

While national railway organisations sometimes engage in the market for long-distance coach services as well, this market is more generally characterised by competition among private coach services. And while the majority of these service providers focus on long-distance point-to-point services with intermediate stops along the route, some service may be characterised as somewhat integrated networks with interchange connections.

Long-distance transport service providers are responsible for the planning, production and marketing of their services out of commercial motivation, consideration of minimum service conditions in the case of franchised services, or a contractual agreement in the case of a service tender. These state-owned rail operators often operate large networks with interchange connections, often not primarily out of business-economic interest but rather the state's societal interest as shareholder. In some instances, as in Japan, long-distance rail operators may seek to co-ordinate with or deploy other, more local transport services (taxis, shuttles, etc.). The aim would be to extend the catchment areas of their stations and increase the range of destinations that their passengers can conveniently reach – especially for tourism-related travel.

Supply-driven public transport services

Supply-driven public transport services are, like their long-distance counterparts, produced according to a predefined schedule and route regardless of the actual demand, with the customer taking the passive role of a passenger. The differentiation between long-distance and public transport services in a regional or metropolitan setting is often blurred and typically comes down to market governance aspects. These public transport services comprise services essential for well-functioning urban mobility – especially for more dense urban contexts and those well served by core radial networks.

The market for regional, metropolitan and local public transport services originated when private transport companies invested in infrastructure and vehicles to provide commercial services. This market configuration suffers from deficiencies that are generally associated with networked markets.

To address such deficiencies and mitigate the loss of passengers that accompanied the growth of automobile use, operators frequently integrated into larger transport companies, often with the state or city as an important shareholder. While this solved certain inefficiencies and facilitated easier journeys throughout a city or region, other deficiencies occurred – like stagnant investment and innovation, associated with monopolist market structures.

In many public transport systems, the services are based on competition *for* the market. In these schemes, one transport operator is granted a localised monopoly. This monopoly may be based on historic developments, the public ownership status of the operator, or a time-bound concession contract awarded through a tender or licensing process to a private operator. There is no competition of operators for the same customers on the same routes in this type of market. Through "competition for the market" instead of "competition in the market", many governments have successfully addressed deficiencies of network markets and monopolistic setups. The influence of local and regional governments on the actual service design and operational characteristics varies greatly, both among countries and among regions within a country.

Regional, metropolitan and local public transport systems comprise a variety of transport modes, including regional, commuter and suburban rail services, Underground services, trams, street cars and light rail, as well as regional and urban bus and bus rapid transit services. Where geography permits, local ferries and water taxis or cable cars may fall into this category as well.

Who is involved?

The organisation of regional, metropolitan and local public transport is often allocated to public transport authorities (PTAs), which are either departments of local or regional authorities, specialised authority bodies, or public management organisations set up and owned by municipalities, counties, regions, federal states, or a combination thereof. Their setup and ownership structure depends on the administrative structure of their respective countries.

According to the market guidelines, concession, or awarding contract of the PTA (depending on its power in the respective market structure), public transport operators (PTOs) produce the actual transport services. PTOs can be commercial organisations or semi-private entities that act commercially, like the regional public transport subsidiaries of national railway companies. These organisations are technically state-owned but act commercially by competing in tenders internationally. In addition to these commercially motivated transport operators, the market also includes public transport operators owned by municipalities, regions or states. In increasingly rare cases, public transport and local authorities operate (parts of) their transport services themselves as an in-house operation. The reason publicly owned transport operators endure is the very capital- and skill- intensive nature of these systems. Despite low operating margins, they are able to generate high societal returns for certain public transport systems, especially rail-based modes like trams, light rail and the Underground.

Depending on the administrative and market structure, roles for service design and development, operation and customer service are distributed among local authorities, PTAs and transport operators. Service design and development roles include defining the routes, timetables, fares and enlargement of the network. Operational roles include dispatching and scheduling of vehicles and staff, maintenance, and incident management. Customer service roles include among others customer information, marketing and dispute management, the operation of points of sale and respective sales infrastructure, call centres, service desks and smartphone applications. Because of the network effects public transport services, operating a sufficiently broad and accessibility-enhancing service may not be possible on a commercially remunerative basis. PTAs address this by granting exclusive rights to operators within a market and/or by compensating them for non-remunerative but socially desirable services via public service obligations (PSOs). These outline reciprocal rights and responsibilities of PTAs and PTOs and, in particular, define service quality and coverage objectives for the latter (EC, 2021).

Demand-responsive public transport

Demand-responsive public transport (DRPT), or flexible public transport services, are gaining in popularity in various countries and regions as a complement to or replacement for existing supply-driven public transport. These transportation services are characterised by some form of flexibility in their operation as the term suggests, they respond to a summons by a passenger. This request must be made with a certain lead time via hotline, website or smartphone application. The service is not produced if there is no passenger demanding it. Demand-responsive public transport exists with various degrees of flexibility, which have been enhanced via application platform-based technologies. Services may follow a specified route and timetable but be produced only in case of an indicated passenger demand. They may operate without timetables but rather be produced at the time requested by the passengers. Or, services may be fully flexible, with routes and times defined on the fly in response to passenger demand. Demand-responsive public transport leverages the intelligent clustering of passenger ride requests into logical routes and schedules to produce highest possible service level with the least possible deployment of vehicles.

Who is involved?

Depending on the administrative and market structure, demand-responsive public transport may be part of a public transport concession, with the same operator producing DRPT and fixed-line, scheduled services. The system may also be tendered to a separate transport operator or general contractor, who takes care of the service design and dispatching function and organises the actual transport production with local transport operators. The service design and dispatching function may also be allocated at the PTA itself, taken care of in-house or with a contracted dispatching service provider, with the transport production taken care of by contracted transport operators and taxi companies. Some DRPT services may be directly co-ordinated with PTO scheduled services, in order to manage first- and last-kilometre demand from PTO stations or stops. Dependent on the setup, services may be produced with designated vehicles or generic fleets of (mini-)buses and taxis. A distribution of the service design, operational and customer service roles similar to that for public transport applies, and is distributed among PTAs, DRPT operators and dispatching service providers, if applicable. A particular service design role is the determination of the system's minimum and maximum lead times.

Shared ride-sourcing services

Shared ride-sourcing describes transportation services provided by commercial or non-profit actors based on the dynamic adjustment of routes to combine the transport demands of various passenger parties transported in the same vehicle simultaneously, despite their journey having different origins and destinations. The customer takes on the passive role of a passenger. The services use smartphone and geolocation technology to match bookings made in an app with the vehicle that follows a route best matched to rider requests. Passengers are usually guided to a nearby location, often described as "virtual stop" for the pickup. The vehicle then continues its journey along the route that most efficiently combines as much passenger demand as possible, while providing acceptable journey times to the passengers already in the vehicle. Some services are community-based on-demand services with volunteer drivers and local commerce, or industry sponsored. In Germany, there are more than 400 of these services some of which are being integrated with public transport apps or which have developed their own apps. Many exist in the United Kingdom as well. They have become very important players in some cases, competing with commercial bus services. This service exists in practice has been modelled extensively by the ITF as well (ITF, 2016).

Platform-mediated informal transit services are also present in many regions (Pollio, 2021). Informal jitney services meet the mobility needs of many populations in developing countries, as well as the needs of certain low-income and migrant populations in more developed countries. For example, jitneys complement missing transport services in suburban areas in New York City and improve accessibility for low-income households that do not have credit cards (Kirk, 2017). The distinctions between formal and informal work arrangements are not always clear, leading certain online platforms to take advantage of this ambiguity to develop and provide services (Van Doorn, Ferrari and Graham, 2020).

Due to the flexible nature and dynamic matching of fleets' capacity and demand, travel times can vary significantly. Service providers often employ dynamic pricing models that base the price of a journey on real-time market demand. This pricing model may lead to significant price fluctuations. The heart of the service is a digital platform that facilitates the matching of passenger demand and vehicle capacity.

Who is involved?

The actual service provider may be the provider of the platform (commercial transport app, CTA) or a different party that uses the platform technology on a white label basis. For the production of actual transport capacity on the road, various configurations exist. One model is based on freelancers using their own private automobile or van to ride services for shared ride-sourcing service provider (e.g. UberPool in some countries). Platforms may attract licensed taxi drivers using their official taxi vehicles to produce the transport service (e.g. UberPool, Lyft Line). The service provider may partner with an original equipment manufacturer (OEM) or other fleet operator for the production of transport capacity (e.g. Via). Or, the service provider has its own fleet of vehicles and driving staff to produce the services (e.g. MOIA). These types of on-demand van services have proved to be more difficult to operate; several operators have closed down their services (e.g. Bridj, Kutsuplus, Chariot). However, platforms such as Via, which provide mobility services by larger-capacity vans and minibuses offering pop-up routes and are designed to have less empty-vehicle travel distances and higher occupancies, seem to have found promising models.

Industry players use the term "ride sharing" to describe this type of transportation product. Arguably the term is misleading, as it is more widely used for peer-to-peer transport or carpooling, in which the journey specifics depend on the car owners' transport needs, not the transport demand of paying passengers. Actual production of this transport service may be based on commercially operated fleets (e.g. Via) or on the basis of vetted freelance contractors (e.g. Jetty) using their own vehicles.

Taxi and ride-sourcing services

This service delivery model has two subcategories: private-hire sourcing services and taxis. Taxis are vehicles for passenger transport that are licensed to operate in public spaces and take on passengers who either hail them on the street, reserve them via dispatch service centres or walk up to dedicated taxi ranks. Taxi services are based on strict regulatory frameworks that typically address market entry conditions, licensing of qualified providers, vehicle certification and appearance, training and safety rules, and operational aspects (e.g. regulation preventing taxis from participating in ride-sourcing, thus preventing multiple parties being served simultaneously).

In contrast to taxis, private-hire ride-sourcing services are not licensed to take on passengers on the street and cannot use taxi ranks. The service is based on prearranged reservations and fares.

With the market entry of CTAs for ride-sourcing (e.g. Didi, Uber, Lyft, Bolt, Ola, Grab), the lead times and inconveniences associated with reserving private-hire ride services were reduced drastically, sparking fierce competition between licensed taxis and private-hire ride-sourcing services.

CTAs are platforms that, as mentioned above, match passengers' transport demand and the available supply of vehicle capacity. A customer-facing application facilitates the booking and a driver application navigates drivers to the subsequent pick-up and drop-off locations. Payment is often facilitated digitally within the app. CTAs may specialise in matching passengers to different types of services within their own application environment (e.g. ranging from vetted but non-professional drivers to different classes and sizes of vehicles and different types of drivers and professional services). Or, they may cater to different types of vehicles including motorised two-wheelers (e.g. Gojek in Indonesia). In a number of markets, ride-sourcing CTAs have expanded the range of services offered beyond mobility. Food delivery is the dominant service represented by this hybridisation. In Asia, however, these services include parcel delivery/courier services and bringing service workers directly to clients' locations (e.g. cleaning personnel, personal care or healthcare personnel, home-work trades including plumbers, electricians, etc.).

Trips sourced through CTAs typically involve short passenger journeys, mostly less than 15 km, but also include some longer ones, up to 50 km – to and from airports, for example. These services also target metropolitan areas, where ride frequency tends to be high and travel distance is usually short (Mittal, 2019). Although major global players in ride-sourcing are relatively newly founded (just five to ten years ago: Uber in 2009, Ola in 2010, and Didi, Grab and Lyft in 2012), they achieved between 15 and 20 billion rides in 2018 in that relatively short period (ITF, 2020a). Prior to the travel restrictions caused by the Covid-19 pandemic, the ride-sourcing industry marked rapid and extensive growth in all global regions.

Ride-sourcing CTAs operate on the model of a two-sided platform where both riders and drivers use the ride matching service of the platform to meet their respective needs for rides and clients. Typically with platform services, an increase in one side of the market (riders) leads to an increase in the other (drivers). Conversely, an increase in the number of drivers operating on the platform leads to a drop in wait times and improves service quality for riders, which makes the service more attractive to people. This cycle is constrained by the limits to wait-time improvements imposed by congestion that these services may not cause but to which they contribute.

Who is involved?

The taxi market is characterised by a large number of small and medium-sized taxi companies. These companies often use the services of dispatching service centres, which may provide a hotline, website and smartphone application for booking. The dispatch services may act as an overarching taxi brand, sometimes guaranteeing a certain service level. Taxis may also engage with providers of taxi smartphone applications outside of the established dispatch centres to enlarge their reach (e.g. Didi, MyTaxi). Taxi regulation jurisdiction differs widely. In one country or region responsibilities may be allocated to national agencies, while in others city authorities or even sector-specific regulatory bodies are responsible.

The market for private-hire ride services is characterised by many small and medium-size companies that often specialise in catering to certain transport needs (e.g. airport transfers). Regulation of these services varies greatly. In some countries, private-hire ride services may only provide journeys over a certain trip length to avoid competition with taxis. However, in general, private-hire ride services are regulated more lightly than taxis.

Commercial transport app services are operated either by the software companies developing the platform directly, or by third party organisations on a white-label basis. For the production of the actual transport service, CTAs sparked the market entry of untrained drivers, using their private vehicles to produce transport capacity for CTAs on a freelance basis. This practice has been outlawed in many countries for reasons of road safety, social and price dumping and worker protection concerns. In countries where regulation was tightened, CTAs use official private-hire ride service companies and taxi companies.

Car sharing and rental services (and cargo vehicles)

Car sharing and rental services provide customers with an automobile that is at their disposal exclusively for the rental period. Customers are provided with the transport asset only and take on the active role of driver. Car sharing and rental services can be categorised into station-based and free-floating services.

Station-based services provide access to the rental vehicle at predefined, dedicated locations. These car sharing and rental stations exist in the form of facilities with staff at the dedicated business premises of the service provider (comparable to a garage) or a service counter and dedicated parking lot (e.g. at airports or train stations). Self-service stations, where the customer starts and ends the rental via a smartphone application using geolocation technology, simply require a dedicated parking spot in a garage or on the street. With station-based services, two different operational models exist that are based on either round-trip or one-way rentals. In round-trip or A-to-A service, customers begin and end their journey at the same location, while one-way (A-to-B) services allow customers to end the rental at a different facility.

With free-floating services, vehicles do not have predetermined parking locations or reserved parking spots but may be parked at any legal parking spot within the geofenced business perimeter of the service provider. Customers can begin their journey at the car nearest to their location and end the journey (and rental) at any location within the service providers’ business perimeter, which usually comprises the more densely populated areas of cities. Some service providers have small, dedicated business perimeters at specific points of interest (e.g. airports, shopping and entertainment centres) to allow journeys to end at these locations, despite their being situated outside the general business perimeter of the respective city. Some service providers allow journeys to end in their business perimeters in a different city. The uptake of professional fleet-based schemes is linked to: 1) high-income groups (greater capacity for travel by car – car sharing is significant in the United States and Europe); 2) high population densities in the city and higher modal diversification (Asia is the largest car-sharing region measured by membership, followed by Europe); and 3) fewer concerns about safety (Latin America is lagging behind other markets) (ITF, 2020a).

The concept of sharing and rental can be differentiated by their product characteristics. With sharing services users must perform an initial registration process, where their identity and permits (e.g. driver’s licence) are checked. After this registration – which is usually performed using online identification services – reservation, pickup and returns are self-service and app-based. Sharing services are thus not limited by office hours. The car-sharing bundle generally includes most cost factors of a journey, like the vehicle, fuel and insurance, and in the case of free-floating services even parking within the business area of the service. The service is usually billed on a pay-per-minute basis or through time or distance packages, or a combination thereof. The service is typically designed for short rental periods of less than a day.

Rental services usually employ personnel for the handover procedures and do not require registration or identification in advance. Their product includes the cost of renting the vehicle only, with the additional costs of the journey – for fuel, tolls, or parking – borne by the customer separately.

Cargo vehicle sharing and rental services essentially describe car-sharing and rental services with vehicle types and product propositions that cater specifically to the transportation of personal cargo. Customers are provided with the transport asset only and take on the active role of the driver themselves. These services generally take the form of station-based services, with either serviced or app-based self-service stations.

Who is involved?

Car rental is an established sector in many countries, characterised by large, multinational service providers with a dense network of rental facilities. Car-sharing services are a newer phenomenon, building on the more recent introduction of smartphone and geolocation technology. There are various types of car-sharing service providers: those commercially motivated; commercial service providers operating under the public service contract of a local authority; and services provided by public sector organisations (e.g. by city utility companies or public transport operators). Several large co-operatives provide commercial car-sharing services as well.

Both professional and peer-to-peer car-sharing display upward trends in membership and cars used in professional schemes across all global regions, with a strong acceleration in 2016, especially in Asia (Shaheen, Cohen and Jaffee, 2018). Factors such as urbanisation and policy promotion (such as changes in the allocation of land/road space availability resulting in decreased availability of parking, pricing of parking spaces, restriction of access to privately owned vehicles to certain parts of the city) are main determinants of the increase in supply and demand for car sharing (Erich, 2018). Barriers to the use of car sharing such as the increased need for planning (loss of convenience) and the perceived lack of vehicle availability (or high cost), as well as other entry barriers (membership requirements) were eased by the shift of these services to digital interfaces and platforms. Changes in customer preferences (also affected by greater exposure to digitally enabled shared business models for mobility) and decreases in electric car prices are expected to lead to rising global adoption in the future (ITF, 2020c). On the other hand, recently (but before the Covid-19 pandemic) the uncertain state of the global mobility environment and operating costs have led to key carmakers with a large presence in the car sharing industry, such as BMW and Daimler, leaving the North American market to refocus operations on specific cities in Europe (Shepardson, 2019).

In the case of a public service contract and with station-based car sharing in general, local or transport authorities may have a significant impact in the definition of the service level, either directly through contractual terms or indirectly through provision of a public parking spot as a dedicated car-sharing station. For the governance of commercial services, especially free-floating services, cities may introduce licensing requirements or demands concerning the use of off-street parking facilities. Many cities, however, do not exert such regulatory power and rather consider car-sharing vehicles as normal vehicles that may park in public parking spots as long as the service provider pays potential parking fees. For services that are not defined by public service contracts, service providers need to design the service, in addition to taking on the operational and customer service roles. This includes the design of an eventually commercially viable service with an effective business perimeter, station locations and marketing. The operational role concerns maintenance and fleet management, which may include the repositioning of vehicles. The customer service role concerns staff at facilities, digital registration procedures and the app, as well as call centres and other customer service channels. There is no distinct border between the rental and sharing service concept: service providers increasingly often operate both types of service.

Shared micromobility services

Micromobility can be defined as personal transportation by means of devices and vehicles weighing up to 350 kg and whose power-assist, if present, is cut off at a speed not exceeding 45 km/h (ITF, 2020b). E-push scooter and bicycle-sharing services are part of a wider variety of shared micromobility options, along with the sharing of other light mobility devices. Light micromobility devices, i.e. those with power-assist that cuts off at 25 km/h and which do not weigh more than 35 kg, form the bulk of the micromobility devices deployed. The uptake of heavier and speedier types of micromobility – mopeds and motor scooters – is much slower (ITF, 2020b). Nonetheless, these services are growing, at least in terms of their availability:

Friedel (2020) notes their presence in more than 40 European cities, and their expansion in the United States is also under way (Toll, 2019).

As the market is still maturing, many new vehicles and designs are being deployed, prompting some authorities to issue guidance and type approval regulations. Sharing services for e-push scooters, e-mopeds, bikes and e-bikes are more centred on metropolitan areas compared with ride-sourcing services. This is because an even greater number of their trips involve short distances and are more frequent, in line with urban travel trends. The vast majority of trips taken by individuals are short passenger trips (i.e. those for which bicycles and other forms of light micromobility hold the greatest appeal).

Shared e-push scooter-sharing services

Shared e-push scooter services provide customers with a vehicle that is at their disposal exclusively for the rental period. These services have started out as free-floating systems with a set business perimeter. Vehicles are either equipped with exchangeable batteries or are collected by operators for recharging. In many cities, parking of e-push scooters is regulated more narrowly after the fast propagation of such services, requiring the use of geofencing technology or the use of specified parking bays which limit where vehicles may be parked. With such regulatory approaches, the system characteristics become more comparable to a station-based sharing service, which increases further in cities that additionally dedicate and reserve specific areas in the public space exclusively for the parking of shared micromobility vehicles. Trips undertaken by shared e-push scooters are typically shorter in length than bicycle or moped-based micromobility services.

Shared e-push scooter services are provided by commercial service providers. Companies such as Lime and Bird (both founded in 2017) started sharing dockless e-scooters in the United States and are now joined by many other companies, some of which incorporate their offer within app-based platforms (e.g. Jump and now Lime in the Uber app, Lime in the Google Maps app). Data from Lime published in (Ajao 2019) indicate that after their initial launch, which took place primarily in the United States, usage of e-scooters grew very quickly, reaching one million rides after 31 weeks and six million rides after 58 weeks. This trend shows that supply and demand grew very quickly, beyond what was observed for ride-sourcing based on cars or vans (ITF, 2020a).

While these services have met with broad consumer success, their deployment has posed challenges to public authorities. Operators still face difficulty finding a remunerative and viable business model. In order to address impacts on public space, some cities have introduced licensing programmes to limit fleet size and the number of operators, and to induce good conduct from operators. These may be static and renewable at set periods, or dynamic and adjustable in terms of fleet caps based on asset usage rates. Many cities have used the introduction of shared e-push scooters (and bicycles) to impose data-sharing frameworks that will help monitor the impact of these new services, and to calibrate public policy responses. Analogous data-sharing requirements are rarely imposed for other services. The market is also characterised with a rate of churn that has seen many operators arrive and leave suddenly. This poses challenges in terms of authorities' being able to achieve public policy objectives that build on the presence and use of these services. These challenges are also relevant with respect to dockless bike sharing.

Bike- and e-bike sharing and rental services (and cargo bikes)

Bike sharing and rental service provide customers with a bicycle, which is at their disposal exclusively for the rental period. Bike sharing has evolved rapidly over the past decade, as demonstrated by data on the number of public-use self-service bicycles worldwide. These increased from fewer than 400 000 in 2010 to more than 1.2 million in 2015, more than 10 million in 2017 (Schönberg, Dyskin and Ewer, 2018), and almost 18 million in 2020 (Meddin et al., n.d.). From 2015 onwards, the huge rise in bike-sharing schemes has been driven by very rapid deployment in China, though many players have merged or left the Chinese market. (Chinese-based OFO rapidly shed its foreign operations in 2018 to re-focus on China, and Bluegogo, China's third-largest bikesharing business with 20 million users, ceased operations in 2017). Despite adverse changes that have seen many systems close down due to financial or organisational failures, bike sharing continues to remain relevant and is on the rise today (Nikitas, 2019) and there is some evidence that the global Covid-19 pandemic has led to an increase in usage (ITF, 2021).

Bike sharing is available through a variety of services:

- free-floating bike sharing, which allows the parking of bikes within the business perimeter of the service provider
- station-based bike sharing, where bikes are parked at a dedicated spot in public space, ensured through geofencing or specific bike bracket stations with self-service through smartphone application or a terminal at the station
- station-based services that use facilities in stores or at public transport stations.

Similarly to e-push scooter-sharing services, public authorities are increasingly seeking to guide and constrain where shared bicycles can be parked – often by providing dedicated infrastructure and converting on-street car parking. These initiatives may combine shared bike and other shared micromobility parking – the city of Paris, for example, has converted on-street car parking in order to provide 1 400 dedicated push scooter parking bays and 1 100 mixed bicycle and push scooter parking bays (OpenData Paris, 2021). Such initiatives bring the properties of free-floating services closer to those of station-based service. Shared cargo bikes are generally provided as station-based systems in both self-service and serviced station settings.

In the case of e-bikes, the need for charging in connection with the significant weight of the vehicles (compared to an e-push scooter) is a constraint on the operation of free-floating services, but the use of swappable batteries has the potential to minimise these constraints. E-bikes use electric propulsion to assist the rider (pedal assist) or to power the e-bike independently of rider input (power on demand). The latter operate independently of rider input and do not count as an active transport mode.

Cargo bike sharing is rapidly growing to serve last-kilometre parcel and freight delivery, especially in congested city areas (Blazejewski, Sherriff and Davies, 2020). But these shared cargo bike services are useful for individuals who may have a need for more capacity than a bicycle can provide. In Brussels for example, on-demand the car-sharing platform Cambio has announced a rollout of electric cargo bikes in 2021, with the aim of filling the gap in carrying capacity between a normal bike and the car.

Who is involved?

Free-floating bike-sharing services are often provided by private service providers on a commercial basis. As with e-push scooter-sharing services, some cities have introduced licensing schemes to limit fleet size and the number of operators and to induce good conduct from operators. Some free-floating bike-sharing services were developed under public service contracts. Station-based services, especially those using bike brackets, are generally based on public service contracts or licensing and subsidy agreements with local authorities, even though they are operated by private service providers.

Operators that provide services out of commercial motivation without public service contracts are themselves responsible for the service design, operation, marketing and customer service roles. In systems that are based on public service contracts, some aspects of the service design, marketing and customer service roles may be fulfilled by local and transport authorities (e.g. location of stations, product proposition, branding, dispute resolution service), while the operational role, which includes maintenance and repositioning of vehicles, is allocated to the contracted private operators. In some cities, local or transport authorities or their contracted transport operators operate bike-sharing systems in-house.

From 2015 onwards, the huge rise in bike-sharing schemes was driven by very rapid deployment in China. Bike sharing remains present and relevant in the urban mobility mix despite the contraction or departure of several major players, as noted above (e.g. Jump bikes was sold by Uber to Lime and downsized significantly).

An important evolution in the micromobility market is the growing popularity of the long-term lease market for e-bicycles and e-push scooters. Programmes like the Ile de France region's deployment of leased e-bicycles and e-cargo bikes under the Veligo label (https://www.veligo-location.fr/), the growing popularity of commercial bicycle lease services like Swapfiets (https://swapfiets.com/), and the emergence of long-term e-push scooter rental schemes such as Voi's (https://www.voiscooters.com/long-term-rentals/) (the three accessed 16 June 2021) show that longer-term access to managed fleets of micromobility devices are likely to be part of the future mobility mix as well.

Informal transport and peer-to-peer ride sharing

Peer-to-peer ride sharing involves people undertaking a journey with their personal vehicle and giving rides to other people who agree to share the cost of the journey (e.g. BlaBlaCar). The terms carpooling and ride sharing are used to describe this peer-to-peer concept as well. In contrast to ride-selling services or commercial transport apps that are demand-driven, a peer-to-peer transport journey will also take place if there is no demand from passengers, as the drivers' initial need for displacement prevails. This service delivers significant efficiency gains from increasing vehicle occupancy for car journeys that are undertaken in any case. Such efficiency gains make it a desirable part of the mobility mix though there are limits to the social acceptance of such ad hoc sharing.

To facilitate this collaboration, services have emerged that are often in the form of an online community platform. These services match the indicated transport demand with available drivers who indicate journeys that somewhat match that demand.

Personal goods and urban freight services

Personal goods delivery describes the transportation of cargo and goods from a business to an end-customer or between end-customers by a delivery service provider. Services may be categorised by the type of goods delivered (e.g. pallet goods, generic consumer goods, groceries, meals, post); by the transport mode facilitating the last mile of the delivery to the end-customer (lorry, delivery van, electric delivery vehicle, delivery moped, delivery bike, walking [e.g. mailman]); or by service providers along a spectrum from multinational delivery service provider and post services to commercial delivery apps using freelance personnel.

Asia has seen a sharp uptake in these kinds of platform-mediated urban delivery services. For example, lalamove, an on-demand delivery service originally founded in Hong Kong, China in October 2013 as EasyVan, now operates in Hong Kong, China; Singapore; and Thailand. Grab, Gojek and many other CTAs also provide popular personal goods delivery services – often with the same drivers and vehicles as their passenger services. While the volume of logistics in Asia continues to increase, there are still many areas where logistics systems are not yet fully developed. Therefore, on-demand delivery services are likely to become an increasingly popular way of meeting these needs.

Platform-mediated inter-urban freight pooling is another service delivery model that seeks to improve the efficiency of goods movement. As with app-based intra-urban goods delivery models, these services pool the resources of logistics firms and hauliers across multiple clients. Asia – China in particular – has seen a rapid uptake of these services. Chengdu, for example, has built three centralised distribution centres comprising 1.5 million square metres of standardised storage facilities for use by these and other urban distribution services (Fusheng, 2019).

Emerging tensions in the urban mobility service landscape

The need to adjust policy and regulation to account for emerging technologies, changing circumstances and new travel behaviour is not new – the transitions are rarely smooth and often give rise to frictions that must be managed. The landscape of urban mobility services is broadening and diversifying. Historic incumbents have helped define established service delivery and regulatory models but these have come under pressure from digitally enabled services. While incumbent services – particularly public and informal transport – still dominate in terms of trip numbers, emerging mobility services have rapidly gained traction and attracted travellers. A number of tensions have, or are coming to, the forefront of policy debates. How they are resolved, or not, will shape the market and determine what mobility choices people will have at their disposal in the coming years. This section addresses six of these tensions.

Creating visions and mechanisms for aligning consumer and societal value

Public authorities should be open to new mobility services but monitor their impacts. Technologies and services that improve personal mobility have been and continue to be tremendously popular. This was true for the uptake of public transport, the bicycle, the car, and now for a range of emerging mobility services. Each successive wave of innovation has led to the disruption of existing practices and the emergence of new business models and mobility practices built on new technologies. These new practices emerge because both individuals and market actors derive value from them. While the alignment of (often positive) welfare impacts experienced by individuals and collectively experienced societal impacts is subject to constant adjustment, policy should assume that unless otherwise shown, new mobility practices and innovations improve welfare. Building a consensus and crafting a vision around what future urban mobility should look like, what it should deliver to people, and what societal goals it should contribute to, are essential steps in providing effective guidance for that arbitration. Such visions are embedded in sustainable urban mobility plans (in Europe) or other outcome-oriented long-range regional transport plans elsewhere that help establish that consensus. Determining the impact of mobility services requires monitoring frameworks that are often not in place or are not fit for purpose. This suggests that public authorities – especially at the local and regional level, where many of these services are deployed and where their impacts are most acutely felt – should ensure that sufficiently robust and adaptive monitoring frameworks are in place. These monitoring mechanisms should be broad and outcome-based, and not solely target new or digital services. They can also help inform market access and egress frameworks to support public policy goals.

Managing uncertainty regarding the economics and viability of new business models

Public authorities are challenged by the mix of business and economic models in the urban mobility landscape. Traditional economic and business models of supply-driven network-based collective transport are well understood and accounted for in public policy. The nature of trade-offs between competition, state intervention and desired consumer and social outcomes are generally well known, though regulatory approaches may differ across different urban contexts. A healthy debate is also under way on optimal pricing of public transport services and the structure and scale of subsidies provided for their operation, even if there is broad acceptance of the basic business model underpinning these services (Hörcher and Tirachini, 2020). There is also a broad consensus on the desirability for these services to play a central role in urban areas, and for strategic guidance and investment by public authorities to ensure their long-term presence.

This is not yet the case for many new and emerging mobility services. The economics behind these models combine features of networked services and platform markets (Martens, 2016a), and the economic framework for their operation is not settled given that the models themselves are still evolving. This makes it more challenging to understand if, when and how regulation should be calibrated to ensure social welfare outcomes. Likewise, the business models for these services are in flux and have generally not achieved viability. Urban mobility markets are mostly tight markets where the capital costs necessary to service broad interlinked or spatially distributed networks put pressure on margins that make achieving remunerative revenue streams difficult. In addition, the sector is challenged by regulatory fragmentation across different jurisdictional and administrative silos, which complicates broad and multi-city rollouts of services. The initial deployment and scaling of new mobility services has been paid for by a vast influx of venture capital but, even at scale, many of these services have failed to break even or generate profits from their mobility products alone (Aguilera and Boutueil, 2018). The services are generally more expensive than public transport and, under current pricing levels, may not be affordable for those who are captive public transport users. At the same time, public transport services are themselves typically subsidised for social welfare purposes, complicating uniform regulatory treatment of actors in the market.

The lack of certainty regarding the viability of business models and concerns about affordability make it difficult for public authorities to integrate these types of services into a longer-term vision of and plan for urban mobility. On the other hand, some new mobility services have the potential to deliver improved efficiencies and lower unit costs compared to certain public transport trips. Thus the arrival of new mobility services may ease the risk and financial exposure of the public sector, and shows some potential to complement or even replace in certain circumstances public sector contracted services. There are well-understood reasons to subsidise public transport, and so it seems reasonable to extend this support to other mobility services when these can provide similar social welfare benefits. Designing the mechanism for doing this will challenge authorities to move beyond current public service obligation frameworks and may lead them to exploit the digital nature of these services by putting in place trip-based subsidies. It will also require new and cost-effective audit frameworks to ensure that trip-based subsidies deliver public value.

Aligning regulatory frameworks across the landscape of urban mobility services

A unified framework addressing all urban mobility services is lacking in most cities. The urban mobility landscape is characterised by the co-presence of multiple service providers operating in the same urban context but under different rules and under the authority of different regulatory bodies. Public transport operates under one set of rules and principles, taxis under another, ride-sourcing under still another (often less constraining), and shared micromobility under yet another, often evolving. Each may be overseen by a different agency that rarely reference common, overarching principles. This is not an historic anomaly – transport services have typically operated and been regulated in silos. But it does pose challenges when public authorities want to improve the overall efficiency of the entire mobility ecosystem at the urban scale, as many do. The PTA model emerged to address the siloed operation of public transport at the urban scale and to improve efficiencies in operations and investment. The potential for synergies among modes – as well as the spectre of potentially unproductive competition – suggests a role for an expanded "orchestrator" of all mobility within a functional urban area (FUA) (Crozet and Coldefy, 2021) Such a body would expand on traditional PTA functions to set, monitor compliance with and enforce a common set of market principles for all mobility operators in line with established public policy outcomes. The governing role of authorities should be organised in a market-neutral way, building on ongoing monitoring and data analysis, and observe principles of checks and balances.

Addressing the lack of settled evidence on the impacts of emerging mobility services

Calibrating the regulation of new mobility services requires an understanding of the market failures and external impacts these impose – this understanding is nascent and sometimes contradictory. Much of the discourse around the deployment of new mobility services centres on the double value proposition of better consumer outcomes and improved efficiency with respect to urban mobility. The former clearly seems to hold true given the broad and rapid uptake of these services – though it is still not clear what final market share these services will attain. The second proposition – that of improved efficiency – certainly seems intuitive when comparing the asset-use efficiency of these services to their direct analogues (e.g. ride-sourcing versus a taxi, the amount of use an owned bicycle gets versus a shared bicycle). But this comparison gets muddied and breaks down when looking at other measures of efficiency – particularly those of the use of space and carbon efficiency with its impacts on global climate change (ITF, 2020a). Other impacts to consider include safety, equity, and social aspects related to labour practices.

The type of impacts seen today may not be indicative of those that could be observed over time. The external impacts of new mobility are just starting to be assessed, and early evidence should be seen as indicative of the current market situation at the early stages of uptake of these services. The scope and relative share of impacts imputable to new mobility services versus other mobility options and practices may change as urban structures change; as vehicle fleets are increasingly electrified; and as new behaviours emerge or co-evolve over time. For instance, the uptake of shared micromobility today may have limited car substitution effects in many cities. However, a fully built-out urban environment that caters to and provides extensive, coherent, connected and safe infrastructure for electric bicycles, push scooters and other forms of light electromobility may very well display significant car displacement effects. An example is furnished by the Netherlands, where these changes occurred over half a century ago. The chances of displacement will be all the greater if these modes are co-ordinated with good-quality public transport.

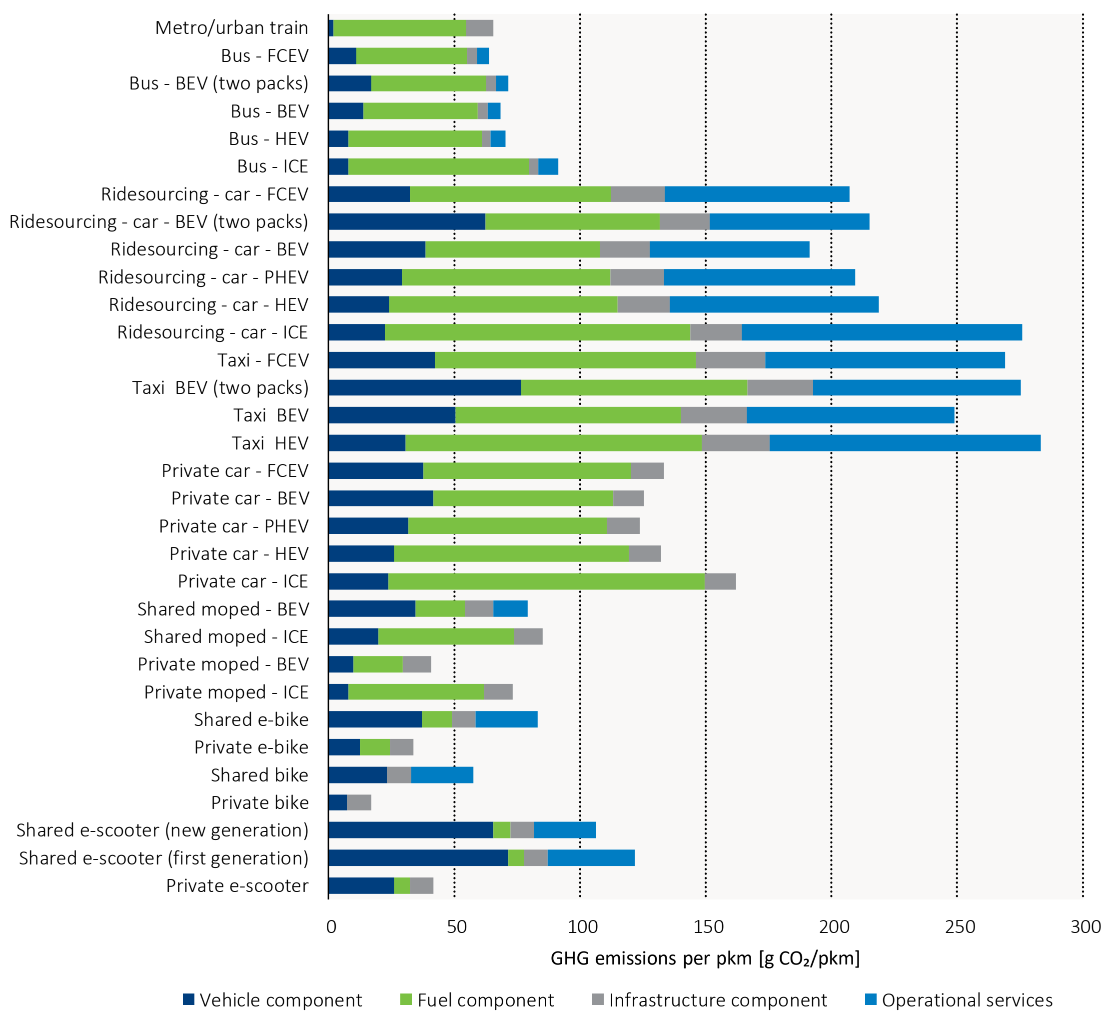
What then can be said about some of these impacts today? Evidence is emerging about the relative energy and CO_2 intensity of various new mobility services. The findings indicate where action is necessary to improve the energy efficiency of new mobility services and reduce their greenhouse gas emissions. Ultimately, overall energy and CO_2 impacts also depend on trip substitution effects, induced travel, and complementarity among mobility services. Evidence is emerging on the issue of complementarity as well.

How do the CO_2 emission intensities of various mobility services compare?

Shared mobility is not necessarily green mobility -- the configuration and operational profiles of mobility services, in addition to the vehicle technology used, have a strong impact on the sustainability of these services. The ITF investigated the life cycle energy and CO_2 intensities of various existing and emerging mobility services (Figure 9)(ITF, 2020). This analysis accounted for upstream and in-use impacts, typical operational profiles and load factors, average vehicle lifetimes and, where relevant, the impact of ancillary operations necessary for service delivery.

Ride-sourcing services and taxis have the highest CO_2 emissions per passenger kilometre travelled of all the modes assessed (including personal car travel). This is true whatever propulsion technology is considered (ITF, 2020; Fernando, Soo, and Doolan, 2020). The reasons for this include empty repositioning and ride-searching travel, empty kilometres travelled from home to working areas and low load factors. In the ITF analysis, taxis perform worse than ride-sourcing vehicles because they have lower utilisation rates. There is evidence that using larger on-demand van-based ride-sourcing and pop-up routes that consolidate rider requests would improve environmental performance through higher load factors and more efficient energy use (ITF, 2021d; Tirachini et al., 2020; Santos, 2018).

Figure 9. Central estimates of life-cycle greenhouse gas emissions of urban transport modes per pkm



Notes: BEV = battery electric vehicle; HEV = hybrid electric vehicle; ICE = internal combustion engine; FCEV = fuel cell electric vehicle; PHEV = plug-in hybrid electric vehicle. These estimates have been developed using key inputs (such as average number of passengers, the electricity mix and the ratio of operational km per active km) defined by global averages observed prior to the Covid-19 pandemic. Specific circumstances occurring in different world regions, changes in operational practices and the Covid-19 pandemic should therefore be modelled as individual specific cases, modifying input data accordingly.

Source: ITF (2020).

Shared electric micromobility and motorised moped services have a much lower impact than ride-sourcing, taxis or individual car use, and are about on a par with private mopeds and bus-based public transport. The main factors impacting per passenger kilometre CO_2 emissions include vehicle lifetime (low for shared micromobility vehicles), usage rates and ancillary repositioning, charging and fleet servicing practices. These operational components represent a significant contribution to overall CO_2 emissions.

Privately owned bicycles, e-bikes and e-mopeds have the lowest lifecycle emission profiles on a per-passenger kilometre basis, followed by various forms of rail- or bus-based public transport (at typical load factors) and privately owned mopeds. The fact that the lowest impact modes are not monetisable (walking) or only marginally so (via the purchase of a bicycle or push scooter), or are subsidised is something to consider when thinking how to include them in a digital and commercial urban mobility marketplace. There is little direct commercial incentive to promote these modes in isolation, which raises the need for public authorities to ensure that these options remain attractive and competitive in order to deliver improved environmental outcomes.

Do new mobility services substitute for or complement other services and how does this impact sustainability?

The evidence base regarding whether new mobility services replace or complement existing services is still developing, but these effects seem highly context-dependent. The impact of new mobility services on traffic congestion, road safety, environmental outcomes and equity stem not only from the uptake of each individual service, but from the interaction effects and changes in travel behaviour that emerge as people choose new travel modes. If travel with these services replaces travel with other more impactful modes, then overall impacts decrease. For example, ride-sourcing trips replacing bus trips or a shared e-push scooter trip replacing a walking trip would lead to greater CO_2 emissions alongside other ancillary impacts such as congestion or reduced health outcomes. In some cases, the availability of new mobility services for first- and last kilometre access may lead to an increase in public transport use. The availability of new mobility services may also induce entirely new trips that otherwise would not have been taken. For these reasons, researchers have been acutely interested in the replacement, complementarity and inducement effects of new mobility services.

Ride-sourcing likely contributes to increased vehicle travel and congestion. The interaction effects of ride-sourcing have been the focus of most studies, with variable findings (Tirachini, 2020). There is evidence that while ride-sourcing represents a small share of overall travel, it nonetheless increases overall traffic levels in terms of vehicle kilometres travelled (VKT) across a range of urban contexts (Schaller, 2021; Tirachini et al., 2020; Henao and Marshall, 2019; Tirachini and Gomez-Lobo, 2020). Increased VKT in turn exacerbates congestion at peak hours and in crowded networks (Agarwal, Mani, and Telang, 2019; Nie, 2017). This is especially of concern since 20-40% of ride-sourcing trips take place at peak hours (Beojone and Geroliminis, 2021). In some cases, as in San Francisco, there is evidence that although personal car traffic represents the bulk of congestion, ride-sourcing services are the largest contributor to traffic congestion growth (Erhardt et al., 2019).

Other interaction effects between ride-sourcing and alternative modes are not clear. The impact of ride-sourcing on car ownership is unclear, but car sharing is correlated with lower car ownership rates (ITF, 2020). Evidence on ride-sourcing across global contexts is mixed, though the two greatest substitution effects concern taxis and public transport in most recent studies. Public transport substitution effects are significant across all of the contexts examined in Table 5. Higher car trip substitution effects can be seen in contexts (California and Denver) where car use is more prevalent. The sometimes significant replacement of cycling and walking trips by ride-sourcing is a concern from a health perspective, just as the number of induced trips are a concern from a traffic and environmental perspective.

Table 5. Ride hailing substitution (percentage) for other modes and induced trips

	Boston	Denver	San Francisco	French Cities	Santiago, Chile	Brazilian cities	Chinese cities Didi express	California	
								Generation X	Millennials
Taxi	22.8	9.6	36.0	27.0-32.0	40.7	49.7	39.0	37.3	24.7
Public transport	42.1	22.2	31.0	38.0-45.0	32.5	30.2	37.5	8.0	15.0
Car (driver)	18.0	22.2	6.0	5.0	12.1	10.4	17.2	25.7	20.7
Car (other)		10.6	1.0			8.1		13.3	17.7
Cycling	12.1	11.9	2.0	n/d	1.3	0.3	6.5	8.0	13.4
Walking			7.0	n/d	2.4	0.8			
Other	n/d	11.3	10.0	n/d	5.6	n/d	3.6	3.0	3.6
Induced trip	5.0	12.2	7.0	9.0	5.4	n/d	0.4	4.7	5.0
	Gehrke et al., 2018	Henao and Marshall, 2019	Rayle et al., 2016	6t, 2019	Tirachini and Gomez-Lobo, 2020	De Souza Silva et al., 2018	Tang et al., 2019	Alemi et al., 2018	

Source: Adapted from (Tirachini, 2020) and (ITF, 2020).

Ride-sourcing seems to compete with, rather than complement, public transport. Interaction effects between public transport and ride-sourcing are meaningful since they could potentially complement each other, especially for first- and last-kilometre access. While evidence regarding the direction and nature of this interaction is mixed and depends on a number of factors, more recent and representative studies tend to indicate that the substitution effect is stronger than the complementarity between them (Tirachini, 2020). Nonetheless, since there is evidence that ride-hailing users are more multimodal than car drivers, they likely still use public transport more frequently.

Shared electric micromobility trips mostly replace walking, public transport and taxi trips (ITF, 2020). The replacement of walking trips is a concern when the majority of these micromobility trips are made by non-active electric push scooters. This is because reduced activity levels adversely impact health outcomes. Further, the replacement of an environmentally benign trip with one having even small impacts represents a net increase in environmental burdens. Nonetheless, shared micromobility trips can complement public transport, drawing users to these combined services and away from more environmentally harmful ones. Evidence from extensive integration of cycling networks, station-based bicycle parking, shared bicycle services and public transport services in the Netherlands confirms these synergies (Nello-Deakin and Brömmelstroet, 2021).

Moving to MaaS

What is the promise of MaaS?

Mobility as a service promises a more efficient and user-centred mobility paradigm. It seeks to unbundle separately managed mobility service offers and rebundle their servitised elements into a new consumer-facing offer. This implies a transition away from an ownership-based or single mode access model to one that focuses on convenient access to multiple co-ordinated services offered by various public and private actors. The promise of MaaS builds on two key factors – improved *consumer* utility and increased *system* efficiency.

Improved consumer utility

MaaS promises to place the traveller at the heart of the mobility service ecosystem. Much of the discourse around MaaS focuses on consumer utility that can be delivered through more efficient and convenient multimodal travel. The starting point for this discourse is the assumption that people simply want to get from point A to point B in the most demand-responsive, flexible, convenient, reliable and affordable way. It assumes that, as in other areas of their lives, people want trip experiences that place them in control and that draw on the most convenient options available irrespective of who offers them. Whereas transport has been a siloed world of independent and separately regulated services, MaaS offers a vision for mobility more aligned with other “as a service” models where *usership* is valued more than ownership (Jittrapirom et al., 2017).

Improved system efficiency

MaaS promises more efficient use of underutilised transport assets. At any given time, even at peak periods, cities are flush with unused private and public transport assets and capacity. There are many reasons for this. People value the convenience of personal vehicles and especially the near-instant availability of these. This is one of the reasons why people accept that cars, motorised two-wheelers and bicycles lie mostly unused during the course of a day despite the significant capital investment they represent. While there are many new services emerging, information about their availability is poorly distributed across the travelling public. People may choose to ignore modes with available capacity if they feel these to be unreliable or undesirable. Finally, much available capacity remains unused since it is often scaled for peak demand and no market or strong incentives exists for its off-peak use.

Efficiency improvements promised by MaaS are realised via three broad features The first two concern economies of scale that can be achieved by minimising the amount of space consumed to deliver a service (spatial efficiency) and maximising the usage of transport assets (temporal efficiency) (Wong, Hensher, and Mulley, 2020). The third efficiency feature that MaaS promises to mobilise is the *connective* efficiency with which different mobility services are virtually and physically joined (Veeneman, 2019). Each of these on its own – and all three together – are assumed by proponents of MaaS to deliver greater resource efficiency and improved sustainability outcomes.

New market opportunities

MaaS represents an opportunity for firms and other actors to find and develop new markets. Single mode business models proved to be dependably remunerative and durable in the past, and they are also deeply embedded in current practices, infrastructure and institutions, as highlighted in the section entitled "The imperative to travel better". Nonetheless, selling or renting cars and providing high-quality public transport services remain challenging endeavours as these markets are characterised by high capital investments and thin margins. The confluence of new technologies and service delivery models gives rise to new business opportunities that deliver better returns on capital through higher asset productivity and lower costs.

MaaS and the big bang: Unbundling and rebundling of mobility

The value people derive from mobility is not just the cumulative value of functional attributes for each travel mode. At the core of MaaS is the concept that sufficient consumer value can be unbundled and extracted from existing mobility service delivery models – including from the private car and public transport – and rebundled into a more compelling offer of services. MaaS is seen as greater than the sum of its parts – in part because it putatively allows the convenience and immediacy of access to one mode of transport to be replicated for all travel modes.

The car is often the reference mode in the discussion about what needs to be "unbundled" and what threshold of convenience and access must be met and surpassed by MaaS offers (Hensher et al., 2020). Often, however, the discourse around MaaS only focuses on the functional attributes of the car – availability, convenience, affordability and comfort. These are only one part of the full set of bundled attributes that are associated with car use (or use of any single transport mode). As noted in the section "The imperative to travel better", the car (as well as other transport modes) confers on its users status, affective, emotional and other non-functional benefits that can be highly valued (Sprei and Ginnebaugh, 2018). The extent with which these can be reassociated with MaaS offers will influence its uptake.

What is the shape of MaaS?

MaaS means many things to many people but it almost always means some form of user-focused and digitally mediated access to multiple transport services. MaaS is a term used to describe a number of things: any application of digital technology in support of mobility; apps used to access mobility services; commercial offers built on packages of bundled transport services; or more generally, a broad ecosystem of services and stakeholders that allows people to seamlessly access a range of different transport services, many of them shared. There are dozens of definitions of MaaS from the perspective of service providers and consultants, public authorities and researchers (Cruz and Sarmento, 2020; Lajas and Macário, 2020; Sochor et al., 2018; Jittrapirom et al., 2017). Surprisingly, given the focus on user-centricity, there is little broad public understanding of the term and no real evidence of widespread popular demand for "MaaS" – likely because there are few commercially available and scaled-up MaaS offers and thus little public awareness of the concept.

A succinct and sufficiently generic working definition of MaaS may be the following: *Mobility as a Service uses a digital interface and shared data to efficiently source and manage the provision of transport-related services that meet the mobility requirements of people* (adapted from Datson, 2016).

MaaS involves identifying clients and operators, gathering information about the availability of services and capacity, and managing payment and revenue allocation within a common framework. In some models, customer-facing MaaS may take the form of a subscription to a pre-negotiated package or bundle of services like those offered by the Berlin public transport operator BVG via its Jelbi app (developed by Trafi) or by the Whim app developed by MaaS Global. The offer may also be structured along a "pay-as-you-go" model that co-ordinates services and payment within a common customer-facing environment. Both approaches also may co-exist in the same model. Multiple hybrid forms of commercial MaaS-like services have been deployed by companies such as Didi Chuxing, Uber, Moovel and Fluidtime. Some of these are more limited in scope whereas others – through their coverage, number of mobility services offered and stated goals – are more ambitious.

In practice there is a continuum of MaaS-like arrangements that extend from single operators offering multiple services to an all-encompassing open MaaS platform that federates different and independent transport service providers. On the single operator side of the spectrum are entities that provide vertically integrated services. These might include public transport operators that provide both bus and rail-based services (and shared bicycles as some do) or a commercial operator that provides different classes of taxi or app-based ride services. The other end of the spectrum is currently largely unexplored territory as there are very few cases of a single operational platform that federates most or all transport service providers within an integrated and seamless framework (Jelbi in Berlin being one service that approximates this model).

MaaS is a mobility distribution model. MaaS is an ecosystem in which stakeholders, operators, data and financial flows are all connected via digital interfaces and connections such that people can choose options that best fit their specific needs (Lajas and Macário 2020). The ecosystem-based distribution model framework is a powerful one that is roughly analogous to the system of provision concept described earlier in the section "The imperative to travel better" (Mattioli et al., 2020).

MaaS functional domains

There are three broad functional domains in the MaaS ecosystem: the *production* of mobility services, the *joining* of mobility offers and *informing* travellers of their options.

The production of mobility services

There is no MaaS without mobility operators. The transport services they produce are the basic building blocks necessary to compile an integrated multimodal mobility offer. The existence of a variety of services, their density and coverage in the service area, and their quality regarding capacity and frequency directly define the potential of the MaaS offer to which they contribute. Mobility service operators (outlined in the previous section) draw upon assets to produce transport services. They invest in vehicles, infrastructure, maintenance and staff to deliver scheduled or on-demand services. These operators have traditionally operated independently or in limited partnerships in offering their services to travellers. Their systems for the most part have not been designed for interoperability or, in some cases, are designed only for limited interoperability with other like services (as in the case of regional public transport services). They have also been regulated independently, under different regimes and often by different regulators.

MaaS implies that mobility service operators become more digitally and physically interoperable in order to overcome these silos. To do so, they will need to make all information relating to service – locations of stops, stations or vehicles; timetables and real-time information; and transactions such as ticketing, reservations and fare validation systems – available for integration in dynamic, machine-readable formats.

The joining of mobility offers

At its core, the concept of MaaS requires *the digital joining-up of different transport, information and payment services into a smooth and reliable customer-facing experience.* These services may be provided by a single operator in cases where extensive integration exists, or may involve a MaaS provider bringing together services offered by third parties into a coherent framework. MaaS can and should support the integration of public transport modes, commercial transport services such as ride services, bike and ride sharing and taxis into a comprehensive mobility offer.

Digital integration functions need to consider three dimensions: *service-relevant information*, *service delivery transactions* and *financial transactions*. The information dimension concerns the integration of static and dynamic information regarding infrastructure and transport services that enables seamless information flows across different operators. Static data include aspects such as the location and attributes of infrastructure (e.g. location and characteristics of roads, parking, car-sharing stations, public transport stops), timetables, terms of use and fares. Dynamic information includes real-time information on the network status of service performance like delays, congestion and detours, or service conditions like the current availability of car-sharing vehicles or prices of ride-sourcing services.

The information integration function may be organised by specialised transport data, routing and information services, which may involve public or private sector organisations or public-private partnerships. The function may also be provided by integrated transport data and transaction platforms; these are essentially specialised software providers who market the integrated data, often in connection with white-label front-end solutions, to authorities and transport service providers. MaaS providers may alternatively decide to perform this function in-house.

The service delivery dimension concerns the business transactions that support access to and integration of the systems and infrastructure providers necessary for the reselling of these services. Transactions may include reservation, booking and ticketing systems, validation systems (e.g. for tickets or driver's licences), and unlocking protocols for self-service vehicle-sharing services. The transaction integration dimension may be facilitated by integrated transport data and transaction platforms or by MaaS providers themselves. Additionally, integrated ticketing and reservation platforms, which exist as both public and private sector services in many countries, often with a focus on public transport ticketing, may take on such a role.

The financial transaction dimension concerns the billing and financial clearing or revenue distribution procedure among the various stakeholders involved in the production of the end-customer's journey. This dimension may again be facilitated by integrated transport data and transaction platform providers, or MaaS providers themselves. Established financial clearing providers such as banks and clearing houses, but also payment service providers and Fintech companies, may seek to facilitate this function.

Informing travellers of options

The customer interface is at the heart of the MaaS ecosystem. It is through this interface that travellers are offered trip options that meet their criteria. While the MaaS ecosystem may be broad and deep, travellers only interact with it via a few square centimetres of handheld digital interfaces. This centrality of the digital interface in the MaaS ecosystem raises several issues. The first relates to how transparently choices offered to travellers are served and prioritised. The second relates to whether MaaS requires a single interface or if several alternative interfaces can coexist, building off a common set of shared information about services. The third issue relates to how different stakeholders in the MaaS ecosystem can or want to retain customer-facing brand awareness in the interface for trips they co-produce with other MaaS actors. The MaaS interface is an integral part of the MaaS provider service production process.

What are the functional building blocks for MaaS?

MaaS ecosystems rely on a number of functional processes that ensure a seamless trip-making experience from the customer's perspective. The processes occur irrespective of whether MaaS is delivered by one or several operators or providers. For each of these building blocks there is a series of corresponding technical methods that support them. While the methods are undergoing considerable flux as protocols for databases, identity management, data access and transmission co-evolve, they are largely based on permissioned and API (application programming interface)-mediated access to in-house or cloud-based proprietary databases.

Secure identity and access management – The identity of users, operators and service providers must be established in a trustworthy manner, and this identity must be linked to rights to use services (and thus linked to payment data) or to dispense services (and thus linked to certification and licensing).

Authentication – The identity of users and service providers must be authenticated across multiple services and multiple use cases.

Asset identification – Assets should be identified and data related to them authenticated. Available capacity, location, vehicle condition and type, state of repair, etc. should be discoverable to all processes seeking to fulfil relevant user trip requests.

Service specification – Fulfilling MaaS requests requires cross-platform and easily accessible information about the service types available. These may include on-demand operation, station or station-less sharing, scheduled services, shared versus exclusive use, different service classes, etc.

Routing and connection information – At the heart of MaaS are the back-office mechanisms that join up different services within or across operators so that travellers experience seamless trips. These mechanisms combine real-time routing and, if necessary, connection information so that people can reliably switch from service to service or from mode to mode as if they were just one.

Near-real-time access to information – Asset, routing and connection information should be accessible in as close to real time as possible to reflect the actual trip-making environment, accounting for changes in traffic, off-schedule operation or other factors that might impact the reliability of travel.

Transaction processing and clearing mechanisms – Users accessing services across multiple providers require some form of commonly agreed booking, invoicing, processing and clearing mechanism to ensure that rights are matched to users as they switch from one operator to the next. At the same time, revenue allocation mechanisms must address how operators are to be compensated for their fractional contribution to a total trip chain. These mechanisms should allow all parties to achieve consensus on what resources were used to fulfil a trip and how payments for them were allocated across all actors.

Payment mechanisms – The actual payment mechanism should allow for seamless and unitary payment for services from the customer's perspective, and should be tied into the back-office transaction and clearing mechanisms.

Data logging/sharing and transmission – Data generated by sensor platforms and embarked on vehicles or devices carried by people, and transaction and trip-related data all underpin the delivery of MaaS services. These data are necessary for delivering real-time and high-quality user experiences. In aggregate form, they can also help deliver better overall transport system performance. MaaS operators and providers record this information and either make some of it or, more rarely, all of it available for use by others in the ecosystem. Data access rules are typically set up on a case-by-case basis, as much of the data is commercially valuable and could prove to be an invasion of privacy.

Efficient and secure distribution of information – Data on transactions and trips are the lifeblood of the MaaS ecosystem. A data-sharing framework that quickly and efficiently allows cross-platform sharing of relevant and timely information is a core requirement for MaaS.

MaaS integration levels

MaaS is still very much an evolving concept, and its particular implementations fall along a continuum of levels of operational, informational and transactional integration. This topological approach recognises that MaaS is not a binary concept and that implementations and ecosystems may evolve over time as they scale or achieve greater integration (Sochor et al., 2018). This approach also recognises that there is considerable heterogeneity in MaaS service levels and offers – sometimes even in the same market.

The levels of integration outlined in Table 6, based on Lyons, Hammond, and Mackay, 2019, describe the range of integration that occur on three levels and the corresponding impact on the cognitive load required by travellers at each level. The taxonomy covers *operational* integration, *informational* integration and *transactional* integration, discussed earlier.

Table 6. Levels of MaaS integration

	Level	Description	Explanation
Higher Cognitive User Effort	0	No integration	No operational, informational or transactional integration across modes
	1	Basic integration	Informational integration across (some) modes
	2	Limited integration	Informational integration across (some) modes with some operational integration and/or transactional integration
Lower Cognitive User Effort	3	Partial integration	Some journeys offer a fully integrated experience
	4	Full integration under certain conditions	Full integration under certain conditions: some but not all available modal combinations offer a fully integrated experience
	5	Full integration under all conditions	Full integration under all conditions: full operational, informational and transactional integration across modes for all journeys

Source: Lyons, Hammond and Mackay (2019).

In terms of operational integration, a move from level 0 towards level 5 implies lower interchange penalties and a more seamless door-to-door travel experience. Similarly, in terms of informational integration, a move from level 0 towards level 5 implies more detailed and actionable travel planning and decision support information across more mobility services. Finally, concerning transactional integration, a move from level 0 to level 5 implies greater integration of booking and payment services, from none to reciprocal (or not) deep linking to other mobility service application environments and finally to fully integrated, in-App booking and payment across most or all transport service providers in a single or a limited number of user interfaces. While in ideal circumstances these three domains should co-evolve from low to higher levels of integration, it may be that in practice each domain displays a different level of integration. For instance, full informational integration often exists (e.g. through online travel planning tools) without corresponding levels of operational or transactional integration. The opposite may also be true – for instance the Pasmo/Suica travel cards in Japan offer a high degree of payment/transactional integration among transport operators and other commercial services, without MaaS-like platform services being present in large Japanese urban areas.

These levels of integration have an impact on the cognitive effort required by travellers to undertake multi-modal trips. Less cognitive effort for travellers enhances user-centricity, one of the key value propositions of MaaS. At the low end of the scale, travellers face considerable cognitive efforts as they must inform themselves of different options available, plan trips across different user interfaces and book and pay for travel separately. In essence, all of the integration tasks fall upon the traveller and this may make single mode trips more compelling. At the opposite end of the scale, all of the integration tasks are undertaken by the linked back-office systems of service operators, aggregators and ancillary services (payment processing, insurance, cross-modal identity management, etc.). Level 5 integration eases the cognitive load on the traveller but requires complex interactions among different systems and adapted governance structures.

MaaS light versus MaaS all-in

The value that MaaS provides is perhaps linked more to the share of trip types it covers than the number of mobility options it includes. The taxonomy outlined in Table 6 is silent on when MaaS can be said to exist. However, if MaaS is seen as a distribution model for mobility services as described earlier, then the production of trips can be seen as a marker. This implies that MaaS emerges at level 2 since travellers can not only assess their travel options but also book and pay for trips that are delivered via operational linkages among transport service operators. Once this basic functionality is met by some operators, it is worth asking what added value is provided, and to whom it is provided, by increased levels of integration. This is a relevant question for policy if increased integration improves consumer welfare and is aligned with policy goals but is not naturally delivered through the market. If this is the case, some form of incentivisation or intervention may be necessary.

Integration at levels 4 and 5 implies a full integration of multiple service providers across an increasingly broad set of contexts. Level 5 implies all service operators are integrated everywhere – that is, every mode is accessible via a MaaS interface, wherever one may be. This level of integration is often likened to roaming telecoms' service access models. As with these models, there may be a need for state intervention to incentivise roaming and ensure equal market access for all service providers.

On the other hand, most everyday trips are local and most of them are (and likely will remain) uni- or bi-modal (Pickford and Chung, 2019). Single modes serve as daily trip "anchors" and recourse to other modes' service first- and last-kilometre (or -metre) access needs. Walking is the first among these modes and falls outside the purview of most MaaS schemes, but should not be overlooked as it confers important health and environmental benefits. There is also a risk that walking may be displaced by "monetisable" MaaS services, though this risk may be addressed through the configuration of the built environment and rules relating to its use (in particular with respect to vehicle parking). Binary pairs of complementary services such as public transport and shared micromobility make a natural combination and are already emerging within various MaaS offers. Such limited "one to a few" MaaS deployments may already deliver great value to travellers without going all the way to a "one to all" model, which will be more complex to deliver.

What role for MaaS service providers?

MaaS creates a role for a MaaS service provider or aggregator that has implications for the organisation and regulation of these markets. New market entrants, often comprised of technology start-ups, may take on the role but so may large, well-established incumbent transport service providers or public authorities. This role is implied in many MaaS models but is not necessary to achieve fully integrated MaaS that does not depend on a single interface.

The service provision function describes the actual production of the integrated, multimodal mobility service, which allows multimodaltrip planning, booking and reservation (e.g. public transport ticketing, reserving a rental car), *en route* support (e.g. wayfinding at interchanges), in-trip alteration (e.g. adjustments in case of disruption) and payment. The service provision function therefore needs to consider three dimensions: *service interface*, *service production* and *customer service*.

The service interface dimension concerns the digital front-end interfaces of the service, e.g. the smartphone application and potentially additional interfaces for tablets, desktop computers and browsers. These interfaces may be developed and operated by MaaS providers themselves or by providers of integrated transport data and transaction platforms, who may furnish these interfaces on a white-label basis.

The service production dimensions concern the combination of transport offers into meaningful product offerings for end-customers. This dimension concerns the design of the integrated, multimodal mobility service, including marketing aspects such as pricing, branding and personalisation. MaaS providers typically carry out this function in-house though integrated transport data, and transaction platform providers might offer the service production dimension in their white-label offers.

The customer service function concerns any form of interaction with the customer that deviates from the generic service flow in the digital interface. It may include functions like dispute management, refunds and emergency hotlines, but generic membership services or aspects like reward programmes and business affiliations may be covered as well. In addition to generic customer service functions, service providers may want to amend their offer with additional functions geared to business travel (e.g. billing, HR-software integration, calendar integration). This function is likely facilitated by the MaaS provider itself, but MaaS providers may also outsource these functions to specialised customer service providers. Technology providers may develop generic MaaS-enabling technology products that interested service providers can use to build their customer-facing MaaS service on.

MaaS service-provision stakeholders

A variety of established transport sector stakeholders from the public and private sectors, as well as new entrants and actors from other sectors – especially those with a strong digital footprint or sectors inducing high volumes of travel demand – may have an interest in establishing themselves as a mobility service provider. The following provides an indicative exploration of sectors and organisations that may be interested in entering this market.

Technology start-ups and firms were the first multimodal MaaS service providers though most did not necessarily have a connection to the mobility sector. They are profit-oriented and typically deploy business models aligned with other technology platform-based services.

Local, regional and state authorities may have an interest in providing multimodal mobility services to their citizens and visitors, especially citizens eligible for specific support by the state or community. Transport authorities may seek to enhance their position as integrator of different transport services in their jurisdiction by providing multimodal mobility services. This especially counts for transport authorities that have strong end-customer relationships, for example through a current role in public transport ticketing. Transport authorities that rather delegate customer-facing activities to their contracted operators may be less interested in entering this market themselves.

Infrastructure managers, especially parking operators that offer digital payment or membership services for their parking products, or motorway authorities that already have digital driver information services, may seek to develop these services into full multimodal mobility services.

Transport service providers already have customer-facing services and established sales channels for their respective transport products and may be interested in enhancing these existing services with multimodal offerings. They also may have an interest in combining multimodal offerings directly with their respective transport product as core service.

Consumer organisations or associations such as motoring associations or passenger federations may enter the market of mobility service provision to differentiate their business.

Housing corporations, real estate and project developers may seek to enter this market and provide mobility solutions for their customers – building residents – in order to reduce the demand for car parks, which are expensive to build and take up valuable space in residential and office buildings.

Tourism and other travel-oriented services may have an interest in entering the market of multimodal mobility provision. These often comprise destinations and locations that create high volumes of transport demand. In order to attract the increasing amount of city dwellers who do not own a car and to increase their own accessibility and visibility, business districts and employment centres, exhibition and entertainment centres, hotels and resorts, airport managers and tourist boards and resorts may be interested in providing multimodal mobility services to their customers.

Finally, *other sectors and organisations that already have strong digital products* and have an interest in increasing customer interaction through their interface may see multimodal mobility service provision as a potential additional feature for their service. This may include booking, shopping and product comparison platforms, consumer reward programmes, banks and fintech organisations, social media platforms and communication platforms. Many organisations with a strong digital footprint may have an interest in following the super-app strategy, with the goal of becoming the digital interface that facilitates all aspects of life for their customers, unburdening them from using several digital services.

In order to reach a wide variety of customer segments – especially those not currently travelling by public transport and thus could be living a multimodal lifestyle – a one-size-fits-all mobility service, whether a public or private sector service provider, will not suffice. If multimodal mobility services prove successful as a concept, an array of different service providers targeting different groups of customers through differentiated brand identities and product offerings may prove to be more successful in delivering desired sustainable mobility and resilience outcomes.

What are the business models for MaaS?

Business models for MaaS are nascent, involve interactions between settled service delivery models and emerging ones, and are developing under unclear longer-term market dynamics and regulatory frameworks. MaaS business models are new and still maturing, and this should have a bearing on how they are regulated. For example, when considering business models (and their regulation) a distinction should be made between mobility services (e.g. those that produce trips) and MaaS providers (those that produce multimodal integration). The two are not mutually exclusive – a mobility operator may also provide trip aggregation services.

The economics and business models for mobility service providers are better understood than those of MaaS service providers. The former produce material outputs and the latter derive value from digital services; the difference in the understanding and maturity of business models among and between the two can be substantial. Various forms of public transport, car rental and car-sharing markets build on settled business and economic models. Viable business models for emerging forms of shared micromobility, ride-sourcing and other forms of demand-responsive transport have proved more elusive. Finally, business models for MaaS aggregators are even less settled and face significant uncertainties with respect to value capture and revenue streams. Regulation of the mobility operators is far more developed and understood than the regulation of MaaS providers. This suggests a risk that early over-regulation of MaaS service providers may prevent viable business models from emerging.

Multiple MaaS market configurations exist and it is too early to tell what final configurations the market may have. Early MaaS business models focused either on business-to-customer (B2C) or business-to-government-to-citizen (B2G2C) relationships. Both have strengths and vulnerabilities.

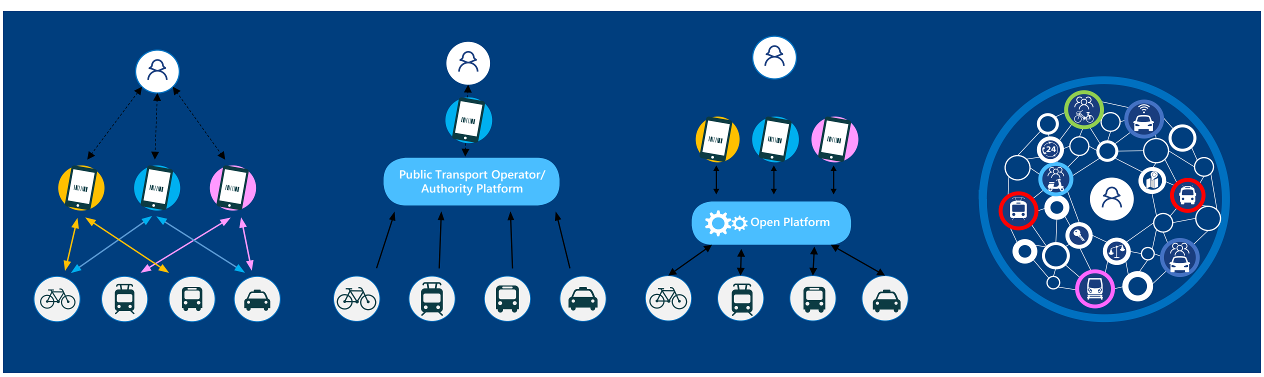
In *B2C markets*, MaaS providers seek to create, customise and market services to the public such that remunerative margins can be achieved. The B2C approach has the potential to maximise innovation and reactivity to customer needs. MaaS providers may present both pay-as-you-go or subscription offers. The latter may give them fewer customers but subscriptions provide them with more predictable revenues. If there is collaboration between the authorities and the MaaS provider, that framework can help achieve public policy objectives. UbiGo (www.ubigo.me) and MaaS Global (Whim – whimapp.com) are examples of this approach. If there is no collaboration or co-ordination, this approach can conversely erode public policy objectives by, for example, cherry-picking the most remunerative trips and eroding public transport revenues.

In *B2G2C markets*, a public entity serves as the MaaS service provider for the whole market. The MaaS platforms in Berlin and Madrid are examples of this approach. B2G2C MaaS offers build on open platforms where affiliation is conditioned on certain (minimal) requirements that ensure alignment with public policy objectives. B2G2C MaaS offers have the benefit of potentially covering the entire market and allowing for direct integration of public policy outcomes. They nonetheless face the criticism that they may be less reactive to consumer needs and changing market conditions or actors, and may not be supportive of actions to improve the business model's viability for commercial actors. B2G2C models are seen as inevitable and a natural end-point, where proponents see parallels between the organisation of MaaS markets and the market organisation of public transport (Crozet, Santos, and Coldefy, 2019; Crozet and Coldefy, 2021).

Another form of MaaS market organisation targets the *business-to-business* (B2B) market. Some B2B MaaS offers aim to help employers manage their employees' work travel and provide added value through management and administrative services to ease the burden on the employer. In Belgium, this B2B model has grown in the context of the mobility budget policy deployed to provide additional flexibility beyond company cars in addressing worker travel benefits. In-app payments do not yet appear to be a feature in these Belgian B2B initiatives, which instead involve the provision of a mobility payment card, usually partnered with a credit card company, to pay for transport services.

An alternative approach to finding a viable business model is not to look to make money from passenger transport alone, but to package mobility with other services that make money, or that can help each other to make money. In Japan, where public transport is generally run by a private company, several companies already offer a prepaid travel card (IC – pay-as-you-go rather than subscription) that can be used for other services, such as shopping and vending machines in the station (Sakai, 2020). One such company, JR East, which offers the Suica prepaid card, has also partnered with Jcoin Pay and Rakuten to expand the range of outlets where the users can pay with Suica (Kurosaki and Higashino,2019). The partnership with Rakuten also allows payments and top-ups for Suica to be carried out through the app (Rakuten, 2020). In other parts of Asia, various ride-sourcing, taxi, parking and other transport services can be paid for via messaging platforms' native payment services (WeChat, Line, Kakao). In Belgium, KBC Bank now offers public transport tickets through its banking app. The bank and insurance company KBC also offers its clients the option of purchasing tickets for public transport and rail tickets within its banking app. This branching out towards "Services as a Service" can also be seen within mobility operator platforms. Uber has branched out from ride-sourcing to food delivery, freight shipping and the B2B market.

Figure 10. Organisational models for Mobility as a Service



Source: ITF (2020), based on UITP (2019).

Several MaaS business models exist and new iterations of these, or entirely new models, are still emerging. Certain commonalities can be identified among them and the typology that follows covers most of those currently observed or discussed in early 2021. They are described using the following category names: Walled Gardens, Public MaaS, Regulated Utility MaaS and "Mesh-y MaaS" (Figure 10).

Walled gardens refers to a business model where a primary mobility service operator, for example a ride-sourcing company, retains the customer relationship/interface and integrates other modes or services, including digital wallets and payment services, that may interest their clients. This model is particularly prevalent in markets where public transport faces quality or convenience challenges and where new mobility services have been quick to capitalise on addressing latent travel demand. The kind of vertical integration of services offered by Didi, Grab and GoJek in various Asian markets, as well as efforts to integrate ride-sourcing, shared micromobility and other services in the Uber and Lyft apps, are forms of walled garden models. There is a discernible trend with some digital platform providers, particularly in Asia, to seek to develop "super apps" that serve as lifestyle support platforms; these include, but extend far beyond, mobility services as described above.

From a public authority perspective, platform providers will seek the best business outcome – which may not result in the best outcomes for public policy goals (Mulley and Nelson, 2020; EMTA, 2019), and demand for discounted tickets or commission could land the public authority with higher costs (Mulley and Nelson, 2020). Furthermore, the public authority's ability to use pricing measures to influence traveller behaviour may be limited in this model, if platforms are free to dictate the prices charged for mobility (Mulley and Nelson, 2020). The walled garden model also raises concerns that a monopolistic operator could emerge if mobility service providers consistently work with just one platform (EMTA, 2019). Data generated in a walled garden environment may largely remain in the control of the private platform, limiting the potential to use it in support of improved planning (EMTA, 2019). There is also the risk that public transport and other mobility service operators might see their customer relationships weakened with combined trips, where they no longer retain the principal customer interface.

The *Public MaaS* model relies on a public transport operator or the public transport authority taking on the role of MaaS aggregator. The public entity acts as a gatekeeper to the MaaS ecosystem and sets the terms for integration of other mobility services onto the platform (and thus with public transport services). In practice, the actual operation of the platform may be undertaken in-house (likely for larger and better-funded public transport operators/authorities) or outsourced under contract.

This model requires an established public transport operator providing a comprehensive network offer; that may happen in certain contexts but certainly not all. Where public transport networks are incomplete or the service offer is fragmented among several uncoordinated suppliers, this model makes less sense. The platform may be fully open (in which case the public entity only ensures that minimal safety, insurance, environmental and other conditions are met) or access to the platform may be more strongly conditioned on specific outcomes. In either case, this model raises the question of trust that new operators may fully participate in the market and that the public entity will not exert monopoly power or otherwise unduly favour its services at the expense of others'. Mobility service providers may perceive a loss of their brand (Mulley and Nelson, 2020) and there would be concerns about losing their customer relationship to the public transport operator.

In terms of development of the system, public transport authorities or operators may lack any comparative advantage in platform development or other key skills of a digital market, which could be beyond their traditional remit and skill sets. Solutions developed are also likely limited to the local transport setting as they are run by the local public entity, limiting their ability to scale internationally or transfer to other cities or regions (EMTA, 2019).

The *Regulated utility MaaS* model explicitly splits the provision (and oversight) of public transport services with the public provision of a MaaS aggregation platform. Oversight of the platform, including the setting and enforcement of platform access rules, is entrusted to the public entity with a broader remit than simply provision of public transport. This model is characterised by a shared back-office aggregation platform that is treated as public infrastructure and that can be used by private MaaS providers who develop their own customer interfaces and apps. Here the MaaS app that the customers interact with can be owned by a separate entity from the MaaS platform, and multiple MaaS apps can operate off the one MaaS platform. The public MaaS platform is managed as a utility and provides common information and transaction integration across all MaaS market actors. This is the model deployed in Vienna with the back-office platform operated by Upstream – a separate but wholly owned subsidiary of the regional public transport operator. This model is also deployed in Lyon and is envisaged for the Ile de France region, with the regional mobility agencies housing and managing the platform (Île-de-France Mobilités, 2020; Crozet and Coldefy, 2021). In practice, this integration can be delivered via a centralised platform or via adoption of common application programming interfaces (APIs) by all mobility service providers – the two are functionally equivalent in terms of market operation (but not in terms of public access to historical data).

Finally, the *Mesh-y MaaS* model is the least explored model of the four presented here. It builds on the distributed API model described above but integrates automated transaction processing, vetting and clearing on the basis of distributed ledger technology (DLT) and automated contracts (ITF, 2018). In this model, the role of aggregator is rendered obsolete through the execution of smart contracts directly between operators. This model would require a high and more uniform level of digital skills penetration among operators and a level of uptake of still nascent DLTs higher than can be found today. More fundamentally, it would require a champion willing to push the uptake of this model. That role may fall on the public sector, given that the principal benefits of such a model would flow to overall efficiency improvements that serve the market and not any particular actor in the market. An early DLT pilot in support of MaaS has been carried out as part of the official national MaaS trials programme in the Netherlands (Mehmet, 2020).

Depending on the starting point in a region, it may be necessary to move through different business and funding models as the MaaS system matures; the MaaS governance framework should not prevent this from happening. The organisational framework for MaaS will greatly influence business models (Mulley and Nelson, 2020), but it is too early to identify the “right” model for MaaS. Given the breadth of contexts in which MaaS is being implemented or considered, there will likely be multiple versions of MaaS organisation and business models over the coming years. The most appropriate model, and the extent to which business models need to change, will only be understood as MaaS systems mature. Policy makers are not in a position to push for the “best” business model at the outset, nor is that necessarily a role they would take on over the longer term if private stakeholders are able to deliver MaaS without eroding public policy outcomes. Nonetheless, business models will be influenced by the way in which the public authority regulates the MaaS market, and the extent to which it plans to be involved in it. Flexibility for public authorities to do both of these things should be retained where it contributes to public policy outcomes.

What are the pricing approaches for MaaS?

The pricing approach adopted is important for the viability of the system, its appeal to users and achievement of targeted outcomes for MaaS. Since its inception, the concept of MaaS has generally been linked to the purchase of subscription packages of mobility, paying a monthly fee as would be done for a mobile phone subscription, or possibly that for another utility. This may be a poor analogy since MaaS cannot be compared to mobile phones, on-demand entertainment or movie platforms because as a proportion of income, its subscription costs are never going to be on the same scale as those services (Pangbourne et al., 2020). The nature of the subscription to a utility company is different too, as there is a single subscription to a single service provider.

From a commercial perspective, in addition to offering a secure and predictable revenue stream, subscriptions offer a way of building loyalty among customers. Research suggests that from a customer perspective, it is preferable to be able to design your own subscription; that ensures the sense of value from purchasing a MaaS subscription, and avoids the sense of being stranded with modes not used while having to spend extra on the modes that are (Sochor 2021)(Ho, Hensher and Reck, 2021). The balance of modes in a subscription is also likely to vary depending on the area the MaaS system is operating in, which could impact margins for the MaaS platforms.

Subscriptions represent a sunk cost in terms of subsequent mobility choices. Having a subscription means that the marginal cost to the user of using one of the modes covered by their subscription is zero, potentially increasing demand beyond what it would otherwise be, or increasing vehicle kilometres where people who previously did not have access to a car now do. If the use of MaaS subscription packages grows beyond niche markets, there is thus a risk for adverse societal outcomes. Modelling suggests that subscription holders crowd out non-subscription holders, who then rely more on their cars (Hörcher and Graham, 2020).

An alternative approach to subscription pricing may be the adoption of a daily cap, like the approach currently used in London on Oyster and bank card payments for public transport services operated by Transport for London (https://tfl.gov.uk/fares/find-fares/tube-and-rail-fares/pay-as-you-go-caps). Under a daily cap an individual trip fare is not reduced but there is a cap at which, once reached, the traveller is no longer charged for their further use of transport on that day. How such an approach would work in a MaaS environment with such different transport modes would need further investigation.

What are the sustainability impacts of MaaS?

MaaS is not necessarily synonymous with sustainability – the environmental and other impacts of MaaS largely depend on a broad regulatory framework that ensures that the uptake of MaaS contributes, or at least does not erode, sustainability outcomes. There is a broad yet untested expectation that MaaS will have positive impacts on the sustainability of travel. This effect would come mainly from substituting more sustainable modes of travel for less sustainable ones (modal share effect), and from better resource use efficiency stemming from higher effective occupancy rates and lower overall levels of travel (activity effect). Higher turnover rates for shared vehicles versus owned vehicles could also result in more rapid penetration of energy efficient technologies (energy efficiency effect). Physical activity and energy efficiency gains are fundamentally linked to patterns of travel activity that are facilitated or generated by MaaS and by the scale of uptake. In many respects, MaaS inherits the sustainability performance of its constitutive mobility services (discussed in the section “The emerging mobility service landscape”) with the additional potential impact from the aggregation of these into an integrated mobility offer. The integration effect of MaaS, especially if it offers key mobility benefits to people, will likely generate new trips as well. This induced travel effect has been significant in other transport domains and there is little reason to believe that it will not enter into play with MaaS. As discussed earlier, there may be threshold effects as well where positive sustainability impacts only emerge at higher levels of market penetration and uptake (ITF,2021c) as MaaS becomes a compelling substitute rather than a complement to prevailing travel choices.

The ITF has undertaken modelling work in the context of its 2021 Transport Outlook to assess what might be the regional contribution of enhanced uptake of MaaS with respect to CO_2 emissions (see discussion of the 2021 ITF Transport Outlook scenarios in the section “Where are we now and what lies ahead”). In the first instance, additional shared mobility and MaaS uptake in line with more ambitious scenarios was applied to the baseline “Recovery” (R) scenario. In the second instance, shared mobility and MaaS improvements were stripped out of the most ambitious decarbonising scenario (R+). This provides two bounds to help frame the impact of MaaS and shared mobility deployment in the ITF Outlook scenarios.

The main initial scenarios are the R and R+ scenarios. The R scenario is equivalent to a “Business as usual” or “Baseline” scenario, for which current trends and official commitments in decarbonising transports are observed. The R+ scenario includes more aggressive policies to tackle transport CO_2 emissions, while remaining feasible. From these two scenarios, additional R + SM (shared mobility) and R+ - SM scenarios were developed to gauge the impact of more or less strongly promoting shared mobility measures. These scenarios help in conducting sensitivity analyses to highlight the impact of shared mobility in the overall results of the main R and R+ scenarios. The R + SM scenario is a variation of the R scenario, with stronger policies supporting shared mobility development, equivalent to the ones in the R+ scenario. The R+ - SM scenario is a variation of the R+ scenario, with weaker policies supporting shared mobility development, equivalent to the ones of the R scenario.

Table 7. CO_2 reductions attributable to Shared Mobility and MaaS in 2050 by world region

Reductions from…	Asia	EEA + Turkey	LAC	MENA	OECD Pacific	SSA	Transition	USA + Canada	Global
Enhanced adoption of Shared Mobility and MaaS in baseline scenario “R”*	+8%	-2%	-14%	-7%	-2%	-20%	-4%	-5%	-5%
The contribution of Shared Mobility and MaaS in the most ambitious scenario “R+”**	+9%	-2%	-17%	-8%	0%	-20%	-6%	-6%	-5%

* This is the difference in CO_2 emissions in the R and R +SM scenarios.

** This results in subtracting the R+ -SM from the R+ scenario.

Source: ITF (2021).

The results show that the contribution of shared mobility and MaaS to CO_2 reductions is largely positive, with a global average of 5% CO_2 reductions across the scenarios modelled. Asia stands out as an exception, where shared mobility uptake leads to increased CO_2 emissions due to shared mobility_vehicle travel growth despite improved load factors. Results also show that regional impacts of shared mobility and MaaS adoption are highly variable. This variability results from the interplay of informal transport substitution effects, improved load factors counterbalancing increased travel per vehicle, and the more rapid penetration of more energy efficient vehicles. Latin America and sub-Saharan Africa are regions where CO_2 reduction from shared mobility and MaaS deployment are relatively high due to efficiency improvements that come from transitioning away from informal transport services. Lower CO_2 reduction benefits in Europe as compared to North America in part translate the starting shares of high-quality public transport in the former and the potential for shared mobility and MaaS to compensate for the lack of these services in the latter.

What is known about MaaS and behaviour change?

MaaS delivers private or public value only if it successfully changes travel behaviours. The potential for MaaS to create new value for individuals and businesses and to support public policy outcomes is only just that – potential – unless people start to adopt MaaS on a meaningful scale. The ability for MaaS to trigger changes in travel and consumer behaviour is therefore at the heart of the MaaS deployment and uptake challenge. In this context, it is worth considering what is known about travel behaviour more generally; what can be learned from relatively small-scale MaaS trials and pilots in the absence of large-scale commercial adoption; and how this might be used to guide efforts to support the uptake of MaaS. It is also important to note that pilots should reflect costs of use that are close to or identical to prices consumers will face in a scaled-up market; otherwise, the pilots do not necessarily send the right picture of user behaviour and adoption.

Travel behaviour and travel decisions are rarely straightforward; they result from multiple arbitrations among a number of factors and opportunities/constraints. They are not, as is often assumed, the result solely of a rational choice based on price, attitudes and preferences (Durand et al., 2018; Zijlstra et al., 2020; Storme et al., 2020; Lyons, Hammond and Mackay, 2019; Ben-Elia and Avineri, 2015). The factors influencing travel behaviour can be broken down into four categories:

- individuals' characteristics
- individual decision-making processes
- the characteristics of different travel options and modes
- factors influencing the decision context.

Individuals' characteristics matter, though they alone do not determine travel choices. They matter because people deploy physical, cognitive and affective (i.e. emotional) efforts in preparing for and undertaking a journey. According to Durand et al., 2018 and Lyons, Hammond, and Mackay, 2019, these efforts are conditioned by a range of factors, including but not limited to:

- age, gender, income
- stage of life
- access to a car or cars, bicycles or other vehicles, public transport pass, etc.
- preferences, priorities, needs, desires
- trip purpose, length
- access to information, knowledge, skill.

Adopting a user perspective improves the chances of triggering MaaS adoption. The diversity of individual's characteristics is precisely what MaaS proposes to address by focusing on the "user perspective" (Lyons, Hammond and Mackay, 2019; MaaS Alliance, 2017). These characteristics and their grouping into various market niches form the basis of much of the work around developing and calibrating MaaS subscription offers. The evidence is far from settled but suggests that targeting specific user groups based on their revealed or inferred travel preferences and behaviours does lead to discernible and possibly durable changes in behaviour (Zijlstra et al., 2020; Durand et al., 2018; Ho, Hensher and Reck, 2021; Reck and Axhausen, 2020; Lyons, Hammond and Mackay, 2019). An equally important finding is that for many targeted users, subscription bundles do not appear to represent a sufficiently compelling offer, and many choose to access MaaS services on a pay-as-you-go basis (Ho, Hensher and Reck, 2021). Finally, as individuals' characteristics – especially relating to household income, access to transport means and trip purposes/lengths – vary depending on regional and national contexts, the type of MaaS offers that are likely to be adopted will also differ. This may lead to very different MaaS products and services across different world regions.

The efficacy of nudging changes in behaviour can be enhanced by accounting for how people actually make decisions. Human decision making is complex (Durand et al., 2018). For instance, multiple and sometimes opposing cognitive processes may be activated when making decisions, and a lot of human behaviour involves avoiding making a choice altogether (Lyons, Hammond and Mackay, 2019; Durand et al., 2018). Individuals frequently make highly subjective decisions. Evidence from research in behavioural economics, for instance, indicates that people tend to overvalue the benefits they derive from their current behaviour and undervalue the gains they might experience from adopting a new behaviour (Storme et al., 2020; Lund, Kerttu and Koglin, 2017). Decision processes may be bound by what is most familiar to a person, or may rely on simple "rules of thumb" to lighten the cognitive loading required to make a decision (Durand et al., 2018).

For these reasons, even if canonical models work on an aggregate level (e.g. for an entire population) they often fail at the individual or sub-group level (Lyons, Hammond and Mackay, 2019). Finally, many individuals may not be open to changing their behaviour. This is especially true of people engaged in habitual behaviour such as particular modes of commuting where they are not even looking to change their behaviour and therefore are much less open to acting on information presented to them (Durand et al., 2018). This suggests that efforts to trigger changes in travel behaviour must be targeted both to individuals (or classes of individuals) and to specific decision points where the likelihood of acting on new information is maximised. Finally. While the links between cognitive processes and behaviour change are well understood in the research community, they are typically better exploited in commercial product design than in the design of policy.

Travel modes display different characteristics and costs that factor into individuals' travel choices. Different modal or service-based characteristics of competing options can dictate individuals' travel decisions. These characteristics include safety, cost, convenience, comfort, reliability, latency, frequency, availability, security, and various non-transport attributes such as status or pleasure (Zijlstra et al., 2020; Durand et al., 2018; Lavieri and Bhat, 2019; Zhao et al., 2020; Schikofsky, Dannewald and Kowald, 2020). These attributes may not be fully known (a traveller may have never experienced some travel options) and often include real as well as perceived characteristics. In this respect, like-for-like comparisons are often hard to make – especially when comparing known versus unknown travel options. This represents an initial barrier to the uptake of MaaS insofar as different MaaS service delivery models are typically new and few people have experience with them. Non-material characteristics such as pleasure and status matter as well, and should be directly factored into MaaS policies and products.

People's travel decisions are bound by what is or is not (or only with difficulty) possible. If good-quality public transport is not available, then choosing to forgo a car or motorbike in return for a transit-centric MaaS subscription is not appealing. Likewise, the choice of using a car in urban settings is predicated on the availability of affordable and convenient parking. Similarly, the propensity to use a bicycle or scooter – shared or owned – may be conditioned by the presence or not of safe infrastructure and speed-limited streets. As noted in the discussion around the system of provision for cars (Mattioli et al., 2020), public and private intervention in the built environment, regulatory frameworks, funding and financing frameworks and relations among stakeholders all help shape individuals' decision-making basis. These also shape societal norms that are in turn embedded in travel decision making. Public authorities can act to shape the decision-making context by for instance actively pricing parking or travel where congestion is present and space is scarce; by actively managing curb access; or by reallocating space from one travel mode to others. The private sector can also nudge behaviour by implementing company mobility management plans. These interventions can contribute to the uptake of MaaS that is aligned with public policy outcomes.

The interplay among these four factors – individual characteristics, cognitive decision-making processes, real or perceived mode and service attributes, and the framing context for travel decisions – comes into play in the uptake of MaaS. In many cases, the interplay among the four has an impact on the success or failure of MaaS pilots. Together, they may help understanding of the scaling challenge faced by MaaS. The complexity of the behaviour change question should temper expectations that simply offering a set of tailored MaaS packages would be sufficient to lead to their adoption. The inertia supporting current mobility practices is deeply embedded and benefits may not sufficiently accrue for key stakeholders to champion MaaS. For this reason, many proponents of MaaS see an enhanced role for public policy to facilitate its uptake and there is a clear need for public authorities to address these behavioural aspects in the design of policies supportive of MaaS uptake.

Direct substitution of MaaS for cars is not a likely outcome of its early rollout. The embeddedness of existing travel behaviour is a significant factor to consider in areas where public authorities hope that MaaS will play a role in reducing car dependence. Evidence indicates that it may be unreasonable to expect that MaaS will provide a compelling substitute to car ownership and use in those contexts for that reason – certainly at first. Rather, MaaS may serve as a complement to prevailing car use by providing a real alternative for some but not all trips made by car (Storme et al., 2020). In fact, much of the value in a MaaS offer beyond what may be already available in the form of a public transport pass resides in the access to cars it grants users either in the form of car sharing or ride-sourcing/taxi use. Those who do not currently have access to a car benefit when a MaaS subscription provides access to cars as an affordable option. For younger generations living in denser urban areas, MaaS may in fact replace or postpone a first car purchase. Those who face real difficulties in undertaking their daily travel without a car require some level of affordable car access bundled into a MaaS offer for the model to be a compelling choice (Storme et al., 2020). In both cases, directly substituting MaaS for car travel is neither a simple matter nor its likelihood high, unless MaaS addresses all four of the travel behaviour decision domains outlined in this section.

A number of specific strategies can draw on understanding of travel decision-making processes to improve the uptake of MaaS (Durand et al., 2018). These include:

- Focusing efforts first on incidental versus habitual trips and at life moments where travel habits are naturally broken or formed.
- Providing a range of MaaS options that enable individuals to customise their travel experiences.
- Addressing real costs, burdens and opportunities as well as people’s *perception* of these.
- Compensating in other ways for compromises regarding traveller autonomy or travel flexibility and reliability.
- Behavioural change support systems (information, customisation, feedback/support, commitment) are important but not sufficient to change behaviour.
- Tying MaaS to broader amenities, lifestyle preferences and life stages.
- Constraining choices where this improves public policy outcomes but alongside the offer of alternative pathways.

What regional MaaS models and scaling challenges exist?

In the context of this project, a number of regional workshops (Europe, North America, Asia and Japan) were organised to discuss implementation and scaling challenges to MaaS in each respective region. The result of these workshops are summarised here.

Challenges to scaling MaaS in Europe

Despite taking an early lead in developing the concept of MaaS and deploying early trials, Europe has yet to see the large-scale adoption of commercially successful MaaS. At the outset, it would be unreasonable and possibly unhelpful to expect MaaS to already achieve the scale that other transport options (and the behaviours associated with them) took years to achieve. Time needed to scale is to be expected, and diversity in different deployments can be helpful in finding the most robust and commercially viable models that align with public policy objectives.

The emergence of B2B MaaS schemes in some European countries is a case in point. In many instances, MaaS deployments have focused on consumer-facing products that require large-scale co-ordination among multiple and oftentimes competing entities. A more limited approach, for example focusing on providing companies with MaaS packages that could complement or replace company cars (where these are popular) could allow rapid if smaller-scale deployment of MaaS. It could also provide space to experiment with MaaS offers that would be more manageable than large-scale deployments.

Another point to keep in mind is that the distinction between deployment and adoption is important. Efforts have been made to deploy multiple MaaS trials but relatively little effort has been made to date with regard to adopting a comprehensive and shared vision for MaaS (at either the regional or national scale) that would facilitate large-scale adoption of services. Without such a vision and framework, too much time is spent on fleshing out lower-level details among authorities and operators and technical aspects of implementation. In this respect, efforts such as Brussels' inclusion of its regulatory reform in support of MaaS within the broader Brussels region's sustainable urban mobility plan ("Good Move") are a helpful model. Authorities can build on this by including a MaaS component (covering platform rules, market entry and exit frameworks, data governance, ticketing, etc…) within their sustainable urban mobility plans (SUMPs).

Lack of trust and/or lack of openness among mobility operators, MaaS service aggregators and public authorities still hinder scaling efforts in Europe. "Walled garden" models, where one entity either vertically integrates all mobility services or otherwise tightly curates entry onto a MaaS platform in order to drive revenue to itself, are seen as particularly problematic from a public policy point of view even though these models are largely prevalent outside Europe. Such approaches may drive innovation and generate value to the users of these services, but they may also lead to suboptimal outcomes from a public policy perspective – especially with regard to competition, impacts on public space, congestion and other negative externalities. Mobility operators – both of new mobility and of traditional public transport – seek to develop "walled gardens" to capture revenue and tightly control user experience. They also do this to protect their brand identity and customer relations. These are understandable motivations but such walled garden approaches may run counter to the broader objectives of public authorities to provide wider and more accessible transport services for all. By restricting access to data, they also prevent value creation that could emerge from broader data-sharing initiatives able to extend beyond transport. The approach leads to inconsistencies that may harm consumer welfare and choice. For example, the Berlin public transport operator's move to open its ticketing platform to one MaaS aggregator is prejudicial to other MaaS aggregators whose presence on the market could drive competition. In another example, Uber refused to integrate its JUMP bikes into a public authority-led MaaS app in the Paris region.

Open access to the market should be the default and any deviation from this position should be justified. Action under way at the level of the EU may settle these sticking points, since by 2030 all public transport ticketing should be available for all operators in mobile formats. In the meantime, at a minimum, public authorities should be transparent with regard to decisions to limit operators and aggregators' access to market.

The timing of regulatory action and reform is also a sticking point in Europe. At present, most public procurement or concession models are not MaaS-ready. These need to be adapted to a broader MaaS framework and away from a modal approach focusing on public transport, bike and scooter sharing. They should also set preconditions for better integration of services by encouraging interoperability and data exchange. However, new MaaS business models have short and rapidly fluctuating timelines whereas regulatory reform is often very slow. There is a risk that there will be many lost opportunities for MaaS deployment while waiting for the emergence of MaaS-ready public procurement models. There is thus a need for another model of regulatory oversight that is perhaps more permissive but more iterative. Part of this approach would entail a shift from a focus on specific outcomes (beyond a series of guardrails to ensure public policy objectives are met) to a focus on full transparency on the process for awarding, adapting and removing concessions or otherwise controlling market entry and exit. Such an approach would entail both broader consultation with industry and a stronger assertion of public action to rectify identified harms. Outcome- and performance-based conditional market entry and exit should be the norm.

Setting in place new transparent legal criteria to assess and guide the development of MaaS is highly challenging, and this difficulty too should not be overlooked. MaaS-ready regulatory frameworks must be developed (at the national level, e.g. Finland, France and Sweden) as well as at the local level, but systemic change reveals tensions and generates pushback. Iterative approaches may be easier but are also suboptimal and may “lock in” structural blockages.

Another barrier to the uptake of MaaS in Europe is the fact that, despite user experience being at the heart of the MaaS concept, too often the user experience of MaaS is not compelling – or at least not as compelling as existing choices. In order to rectify this, many actions must be taken to ensure that the material travel experience is as seamless as that served to travellers within their handheld device (which itself is sometimes perfectible). This entails investments on the part of authorities in infrastructure and modifications to the built environment and wayfinding systems that ensure a smooth and seamless intermodal travel experience. A MaaS app alone, without a supportive built environment, will likely not succeed in changing behaviour, whereas on the other hand changing the built environment may lead to changes in travel behaviour even without a MaaS app. Furthermore, and paradoxically, when the built environment and the quality level of public transport and active travel modes are high, as they often are in the centres of many European cities, there are likely smaller potential returns on investments for MaaS, thus limiting the commercial appeal of deploying such services.

MaaS initiatives are also being trialled in rural and peripheral areas (e.g. in Finland, Denmark and the United Kingdom) with a focus on horizontal pooling of demand, integration of statutory services into one, opening the service to non-subsidised passengers and integration into public transport arterial networks.

Challenges to scaling MaaS in North America

Good-quality public transport is not as widespread North America as in Europe or in some Asian cities, and this will likely shape the rollout of MaaS there. Outside of the largest North American metropolitan areas, public transport is sparse, and even in the largest cities it suffers from poor quality in many cases. Public transport in North America has also been hit particularly strongly by the Covid-19 pandemic and the relatively fragile nature of public transport funding in the region. This raises the question of what a public transport “light” MaaS might look like in North America and what this entails for public policy and market opportunities. In addition to the structural weakness of public transport is the presence, at least in Mexico, of informal transport services – these could be integrated into platform services but the digital literacy of operators is low and tight margins preclude significant investments on their part.

Another key factor is the fragmented nature of regional transport governance – especially in the United States. Getting dozens of independent transit agencies and planning boards to agree to a common framework significantly reduces the scaling opportunities for MaaS. This fragmentation starts at the federal level with little guidance or context-setting from the top down. In some cases, co-ordination is actually prevented due to existing laws and regulations. That may explain why private sector "walled garden" approaches have so successfully taken root in the United States. In the current fragmented context, individual companies can deploy uniform and coherent services more quickly and easily than many public transport operators and authorities.

Given the generally poor quality level of many public transport systems and the preponderance of built environments that support individual car use, MaaS in the United States and Canada may be more tilted towards the use of individual versus mass modes. This may help explain in part the appearance and rapid deployment of ride-sourcing and shared and electrified micromobility in the region. Those modes may serve as a starting point to refocus public transport investments where they have the greatest impact and seek enhanced access via complementary mobility services.

Another potential barrier to broad-scale uptake of MaaS in North America is the lack of physical infrastructure necessary for or in support of MaaS (e.g. allocation of curb space for pickup and drop off, continuous light individual transport infrastructure for safe bicycle and scooter journeys). The Covid-19 pandemic has served as a catalyst for cities to accelerate the deployment of MaaS – supportive infrastructure for shared micromobility and for more dynamic curb space management.

Challenges to scaling MaaS in Asia

In Asia the penetration of digitally enabled services and the development of new mobility services are not uniform, and there is a real divide between higher- and lower-income countries in the scope for the development of MaaS.

In higher-income countries, many public authorities in cities endowed with efficient public transport networks and seamless ticketing systems do not see much added value in MaaS. Some large cities have achieved high levels of transactional integration via widespread adoption of advanced digital payment services. Smart card payment systems have extended beyond transport-only uses over a decade ago in places like Tokyo; Hong Kong, China; and Seoul. These cards allow users to pay not only for transport services but also a range of other services and goods, and thus deal with a broader set of lifestyle behaviours of which mobility is but one part. The conflation of Mobility as a Service into a broader "service as a service" ecosystem and "super-apps" is rapidly developing in Asia. In this context, MaaS is more than just about transport; it is about seamless payment, seamless connection between home, work and play, and seamless interaction with all kinds of services.

Another MaaS-related development in the region and especially in Southeast Asia is the uptake of diversified and hybrid passenger/goods delivery mobility services based on motorised two- and three-wheeled vehicles. The deployment of these services highlights the tension that exists between the affordability of public transport systems and the limited scope for public transport to provide adequate levels of access in sprawling and congested cities. New mobility services can help improve accessibility in these cities when they employ agile motorised two- and three-wheelers (as in the case Grab and GoJek in several Southeast Asian cities), but they are generally more expensive than public transport. Affordability of new mobility services is also a key issue in India, where low-income households do not benefit from the deployment of digitally enabled mobility services. In these contexts, non-digital informal transport still plays an important role in providing access for the poorest while middle-income and wealthier households benefit from more expensive app-based services. From an employment perspective, however, a shift from informal to platform-based mobility services may improve income for drivers.

Public transport in the region, especially in large urban centres, tends to be centrally managed and favoured by public policy. There is typically little operational integration across different mobility service operators, or often even among different public transport operators. Where this integration has been tested in pilots, the results have been promising, as in the case of a two-year MaaS trial in Kaohsiung (Chinese Taipei).

Japan presents a unique case, where national government policy has sought to explore and adapt different MaaS models to specific targeted outcomes. The motivations for seeking to develop MaaS in Japan are diverse and typically go beyond simply wanting to mitigate the traffic, equity and environmental impacts of car use in urban contexts. The challenging context for public transport provision in Japan has shaped the conception and trialling of MaaS there. Population decline poses challenges from the perspective of funding public transport services, while at the same time an ageing population places greater pressure on maintaining public transport for those who cannot or who can no longer drive.

Public transport and rail services are rarely provided by public authorities though the latter do extend subsidies for private operators to maintain services. The profitability of private "public" transport services is achievable in large, high-density urban areas, less so in second- and third-tier cities, and elusive in rural and peripheral areas. Profitability of urban rail services in Japan is linked to the capture of value from passengers via non-mobility amenities (shops, hotels, other Japan Rail-owned services). This model is difficult to replicate outside of urban areas with high volumes of passengers.

The strength of high-quality privately operated public transport systems in Japan in some ways poses barriers to scaling up MaaS offers in urban areas. In those areas, large private operators have an interest in using MaaS-like offers to further channel passengers (and revenues) into their own core services. This ensures a solid base for MaaS. On the other hand, the dominance of incumbents may mean that innovative mobility services offered by third parties may not be able to find a market in Japan. This is especially true given that many new mobility services based on ride-sourcing or shared micromobility are not legal or homologated for public use. MaaS options – especially those targeting first- and last kilometre travel – could enhance the quality of the overall public transport door-to-door experience, but it should be noted that the current first- and last-kilometre trip segments are often significantly skewed to walking, cycling and now e-cycling trips. It is not clear if there is much commercial "space" in this context for introducing paying, shared services to replace walking and own-bike trips.

Deployment of MaaS in Japan is not simply a series of government-led demonstration experiments; some commercial deployments of MaaS are under way. For example, car companies and car dealers are introducing MaaS services in cities such as Yokohama, Kitakyushu and Fukuoka, and in regional areas such as Toyama, Miyazaki, Nichinan and Itoshima. A prime example is My Route, a partnership between Toyota Motor Corporation and the Nishi-Nippon Railroad Co., Ltd. in the Fukuoka area, which won the International Auto Aftermarket Expo (IAAE)'s MaaS and Innovative Business Model Award in the app category in 2020. Yokohama's My Route service combines local public transport with other transport services such as taxis, rental cars (even from competing car companies), bicycle sharing and micro-electric vehicles. My Route includes combined booking and payment for these services.

Because the urban passenger mobility market is well covered by high-quality public transport in Japan – at least in large cities – other transport sectors and first- and last-kilometre logistics in particular may be more suited for scaled-up "Freight as a Service" (FaaS) deployments. This is especially true as the urban logistics sector faces severe driver shortages, and finding ways to expand capacity and quality with the existing driver base can help. This situation is similar to that in other Asian countries (e.g. China, Republic of Korea) where large urban centres have high-quality public transport but at the same time face challenges in the urban logistics sector.

Japan has focused on the deployment of MaaS in rural areas in part to address the challenges of providing traditional public transport services to a declining and ageing rural population. One of the challenges has been to bring key service providers, including taxis, onto digital platforms. This has in part been because local transport service providers (mainly buses and taxis) display lower digital literacy rates, as do their clientele. One essential element to consider is the provision of non-digital, analogue customer service channels (including phone lines) – even though these come at a cost. There may be room here to engage private intermediaries (such as shop owners) to serve as go-betweens in return for a commission/subsidy. Rural MaaS initiatives include the East Japan Railway Company's Tohoku MaaS, which covers more than six prefectures in the northern part of Japan.

Another focus of rural MaaS in Japan has been to target tourists and thus improve regional economic development outcomes. West Japan Railway Company has commercialised a MaaS application called "WESTER", a customer-focused comprehensive concierge service that includes functions such as congestion information and contactless ticket purchase. Launched in September 2020, WESTER is unique in that it is also linked to Setowa, a tourism-oriented MaaS service, as well as existing online reservation services. In addition, Odakyu Electric Railway added train congestion information to its MaaS app EMot, which celebrated its first anniversary in October 2020; Tokyo Metro's "My! Tokyo MaaS" was launched in March 2020; and in November 2020, Tokyu, JR East and Izu Express will launch a tourism MaaS service in the Izu area. November 2020 will also see Tokyu, JR East and Izu Kyuko conducting a MaaS demonstration experiment in the Izu area, and the "Izuko" MaaS app is now in its third iteration.

MaaS governance challenges

MaaS governance requirements: Vision, scope and monitoring

Governance of transport services must consider the regulation of services and conditions of the transport service market, as well as the integration of transport services into multimodal offerings. Governance of MaaS should be vision-led, scaled to the right functional urban area (FUA) and informed by a reactive monitoring and policy adjustment framework.

MaaS should be integrated into a broader vision for transport and urban development. MaaS represents a break with past mobility distribution models, but the outcomes to which it contributes are still very much aligned with existing objectives for urban mobility policies. While these may differ from context to context, they include core outcomes such as safety, efficiency, equity and sustainability. In this respect, MaaS should be situated within a greater vision for urban mobility, including how urban mobility markets – including the MaaS ecosystem – contribute to achieving that vision.

In Europe, this vision is typically the result of the Sustainable Urban Mobility Planning (SUMP) process. *The SUMP process is a "strategic and integrated approach for dealing with the complexity of urban transport. Its core goal is to improve accessibility and quality of life by achieving a shift towards sustainable mobility"* (Rupprecht Consult [editor], 2020). Insofar as these plans exist, they should expressly reference where the MaaS ecosystem fits into that vision and how MaaS is expected to improve outcomes for people and for the city. A good example of a MaaS-specific SUMP is the "Good Move" plan adopted by the Brussels Capital Region (Brussels Mobility, 2020). This plan comprises fifty actions, of which developing MaaS is one, and clearly sets out the objectives that the Brussels Capital Region transport system, and therefore MaaS, needs to deliver. The vision set out in the Good Move plan helps inform the principles for developing the MaaS market and determines the regulations that will be established, in order to ensure that the ultimate ecosystem delivers against societal objectives.

The vision for MaaS should itself be built into broader strategies in support of the digital economy. The Strategic Plan for Mobility in the European Union, for instance, references MaaS within the broader context of the EU objective to help Member States adapt to the digital age. MaaS fits into broader digital governance objectives seeking to create a trustable digital environment that enables private and public actors to share data with each other safely and efficiently (EC, 2020).

Another context-setting approach for MaaS has been adopted in Japan, where analysis of prevailing mobility challenges across a wide range of situations has led to the adoption of several different guiding visions for MaaS, each suited for a specific set of circumstances. These include a more "traditional" vision of urban MaaS helping to alleviate traffic congestion and improve efficiency outcomes by improving use of existing assets; a vision for MaaS that seeks to preserve accessibility for an ageing population in rural contexts; a vision that utilises MaaS to improve returns for mobility service operators facing declining patronage or staff; and a vision for MaaS that seeks to improve regional economic development by promoting tourism in rural and peripheral communities.

MaaS frameworks should cover the effective urban mobility commuter basin. This may mean that, as with the governance of urban mobility, MaaS governance frameworks should extend to the entire FUA. This will require adjusting and aligning institutional responsibilities to deliver on effective FUA mobility governance. Ensuring that mechanisms are in place for seamless travel using MaaS services *between* urban regions – MaaS roaming – may also be of help even if the bulk of daily trips (by definition) occur within FUAs.

Finally, MaaS governance should be informed by a comprehensive mobility monitoring framework that includes, but extends beyond, digitally enabled mobility services. With respect to monitoring the impact of MaaS, some idea of "what success looks like" will be necessary. Mulley and Nelson (2020) suggest that metrics for measuring success should be based on:

- a spatial element: the area covered by the service
- a quantity element: some threshold based on the number, or proportion, of users using MaaS
- a mobility provider element: all (or a defined proportion of) mobility providers are furnishing services through at least one MaaS aggregator.

Establishing the regulatory foundation to support MaaS markets

MaaS requires a regulatory foundation that delivers on necessary outcomes while enabling innovation. MaaS is very much an evolving concept with a promising but uncertain future. It has the potential to create value for people and deliver on public policy outcomes while enabling healthy market opportunities for various stakeholders. It likely requires governance but where and how much are still not settled. It seems premature to talk about what the regulatory framework should look like, as both MaaS and its regulation are likely to change and mature over the near term. Further, what that regulatory framework will eventually look like will differ across countries and urban contexts. Nonetheless, MaaS regulation should be guided by principles that are tested and well understood in other, analogous markets, even though their direct transposition to MaaS may not be suitable without adjustment.

The regulatory treatment of competition in MaaS markets should be as light as possible and as constraining as necessary. Widely accepted competition policy principles suggest that policy should adopt a fundamentally pro-competitive stance. Regulators should impose the minimum level of restrictions on competition necessary to achieve public policy objectives that cannot be achieved effectively in any other way that is less restrictive of competition (see the OECD's Competition Assessment Toolkit [OECD, 2019]). If the business case/model for MaaS aggregators is uncertain, it follows that policy makers should be especially cautious about regulating in ways that restrict fair competition – or, alternatively put, regulating in ways that constrain operators' ability to act freely in the market.

MaaS is a hybrid market requiring an innovative but effective framework that encompasses regulation of mobility services and operators and digital services. Regulation of MaaS ecosystems involves two components – the regulation of mobility services/operators and the regulation of digital platforms and MaaS aggregators. The former is a challenging yet familiar terrain for transport authorities, but many aspects of digital market regulation are uncharted at the regional and local levels where much of the regulatory framework for MaaS will be set.

Aspects of digital service markets in MaaS raise challenges that mobility regulation has yet to address. These include extreme returns to scale, network externalities and incumbency advantages, the role of data and the regulation of digital platforms (Cremer, de Montjoye and Schweitzer, 2019). Some of the competition policy risks that stem from inadequately addressing these regulatory issues are somewhat tempered by the fact that MaaS services have physical components (vehicles and their uses) that are regulated. Nonetheless, the regulation of MaaS aggregator services will require specific approaches.

Box 2. MaaS Alliance Checklist to evaluate well-functioning MaaS markets

The MaaS Alliance has established a checklist to help evaluate the main features of a well-functioning MaaS market that build on elements of mobility and digital service regulation. Those elements are:

1. *Widespread availability of data*
- Access to high-quality and accurate data to ensure fair competition
- Existence of standardised data sets and protocols
- Endorsement of "Open by default" and "Interoperability by design" approaches
- Data reciprocity and incentives for data exchange

2. *Ease of market entry and exit*
- Access to market (new mobility services)
- Access to integration and resale of services
- Non-discriminatory subsidy, incentive and taxation systems that are aligned with policy objectives
- Ability to switch between different service providers (personal + non-personal data portability)
- Inclusivity in terms of modes/services

3. *Existence of business opportunities*
- User buy-in and willingness to pay
- Incentives for innovation
- Commercial viability
- Supportive comprehensive policy framework (flanking policies)
- Funding available for investments

4. *Added-value of partnerships*
- Trust and equity among market players
- Balance in roles and responsibilities

5. *Absence of antitrust issues and abuses of dominance*
- Competition between aggregators/platforms
- No gatekeepers in data, service or integration layers
- Roaming between services and local ecosystems

6. *Achievement of public interest objectives*
- Inclusivity
- Affordability
- Equity
- Less emissions
- Less pollution
- Less congestion
- Less accidents

Source: MaaS Alliance (2021).

Issues and risks to be considered in the governance of mobility services

Mobility is a capital-intensive, low-margin network market – there are limitations to the amount of value that can be captured by commercial actors while still delivering on public policy outcomes. Transport services require physical infrastructure (e.g. roads, railroads, stations) and technical assets (e.g. vehicles) to operate, making it a very capital-intensive sector. The resulting high operating costs leave little room for profit margins. Additionally, transport services operate in networked markets, as infrastructure dependence limits the locational reach of services and with that limits the attractiveness or usefulness of services to specific groups of customers. Not all transport operators (= sellers) can engage with all customers (= buyers). The combination of these three aspects makes the production of commercially viable transport services in an open market challenging.

This dilemma is not a new phenomenon facing digitally enabled mobility services, but is a well-known, underlying problem of urban mobility markets. Addressing this problem led to the development of publicly controlled and subsidised public transport markets in many countries. Japan is a notable exception in this area: private transport operators display a higher degree of freedom from public control or ownership.

With the development of publicly regulated markets, public transport was able to address the deficiencies of networked markets, create meaningful, integrated services for citizens, and find ways to promote entrepreneurship and innovation on the side of operators. The latter must still compete for the market again after each contract period, effectively addressing inefficiency and stagnation issues experienced with large state-owned monopolies. The market penetration of other mobility services may remain limited to dense urban centres without a similar evolution, and this may limit the uptake and spread of MaaS. Even in those otherwise favourable contexts, the difficulty these services have faced in achieving commercial viability is telling. Nonetheless, the impacts of density and value creation may differ across world regions. In the densest and most sprawling urban archetype regions described in the section "The imperative to travel better", the potential for integrated mobility services may be higher than elsewhere – especially if public transport services are limited in their capacity to provide high levels of access.

Transport services require public infrastructure and thus public space to operate, and should utilise this finite resource as efficiently as possible (Crozet and Coldefy, 2021; Crozet, Santos and Coldefy, 2019). Transport services and the vehicles they employ need to be safe, and cities may seek to employ sustainable services and environmentally friendly vehicles only. Transport services need to cover the entire area in question with acceptable levels of service quality. Transport service governance is clearly interlinked with infrastructure and public space governance considerations. Outcomes relating to the efficient and equitable use of public space will have to be addressed, and authorities may wish to ensure that operators' services are aligned with public policy objectives.

Public authorities should carefully consider public welfare outcomes when setting conditions on market entry. If market entry conditions are set, they should be proportionate to identified harms that outweigh benefits. Proposals to regulate new and emerging forms of urban mobility on the basis of actual or feared negative externalities should be approached cautiously. The experience of dockless bikeshare and, to a lesser extent, e-scooters clearly suggests that heavy-handed regulatory approaches could shut down markets that otherwise could deliver benefits to people and support public policy objectives. Market entry based on licensing does not address the issue of market volatility. Many transport service providers have not yet matured into commercially viable businesses, which may result in considerable churn among service providers.

To address challenges caused by excessive turnover in the transport service market, local and transport authorities may seek to procure transport service production through tenders, similar to public transport procurement procedures. While this indeed reduces the risk of service providers unexpectedly exiting, it may also considerably limit innovation. This is especially the case with new mobility services that are still seeking a viable business model. Authorities may also find themselves funding or subsidising poorly performing transport services with limited possibility to exit contracts.

Regardless of the strategy employed, authorities will need address equity concerns regarding the geographic availability of services. Commercial transport services are prone to operate predominantly in very dense urban centres and affluent neighbourhoods, where transport quality already is above average. Effective governance needs to ensure more effective coverage of services throughout the area in question, through smart combination of commercially viable and non-viable areas in licensing packages or through smart concentration of demand at central, visible neighbourhood locations.

Issues and risks that need to be considered in the governance of Mobility as a Service

Revenue-sharing issues

An issue central to the development of MaaS relates to fares or revenue-sharing considerations. Public transport again provides for a good example: it is a transport mode system usually comprised of multiple, overlaying networks of different modes (e.g. regional rail, metro, tram, bus) that are often provided by various operators. With service integration, service hours, timetables and the relevant travel information of each mode are co-ordinated with each other, enabling customers to make meaningful connections in an efficient manner. Without fare integration, however, the customer would still need to pay each leg of the journey that is provided by a different operator separately, which is inconvenient, opaque and often more expensive.

Increasingly, transport operators decide to join forces or become integrated with one another by their public transport authorities depending on the respective administrative- and market structure. With the resulting uniform fare structure, passengers are free to choose the public transport modes and lines within the spatial and temporal validity of their ticket. Customers thus engage with the entire public transport network, rather than specific operators.

To attribute the share of revenue to the respective modes and lines (and thus operators) used with the ticket, while accounting for cost-effectiveness of the ticketing system, revenue attribution models are employed.

In *supply-oriented revenue attribution* models, stakeholders receive revenues depending on their operational conditions, including the volumes of transport supply produced by the stakeholder and cost structures of the modes in which these volumes are supplied. Market developments, demand fluctuation and customer behaviour are not considered in this mode, which reduces the need for measuring and modelling of these parameters and thus the cost for revenue attribution.

In *demand-oriented revenue attribution* models, the actual utilisation of transport services provided by a respective operator are considered. The earning power or tariff yield per line is modelled based on the volumes of passengers using the line and the types of tickets used by these passengers (e.g. more relatively expensive single tickets will lead to higher revenue attribution). The more precise this attribution model is applied, the more data on passenger volumes and ticket types used in a line are required, which results in increasing costs.

In *sales data-dependent attribution*, ticket sales statistics are the basis for the revenue attribution; they classically list the price, the point of sale (which stakeholder sold the ticket) and the type of ticket. For this attribution model, the approximate connection (start and destination) needs to be recorded. For the attribution of subscription pass revenues, this model requires information on the residence and frequent destinations (e.g. workplace, school) of the ticket holder. While considered a cost-effective model that is powerful for single-ticket revenue attribution, that of subscription pass revenue with this model is complicated.

In the *agreement-based revenue attribution*, revenue sharing is based on negotiations among the stakeholders. There is no need for data collection and that makes this model particularly simple and cost-effective. The fairness of the procedure is guaranteed to the extent that all stakeholders negotiate a compromise solution that they themselves consider fair.

Many transport authorities employ hybrid models, combining various models– often differentiated per type of ticket – to combine the strengths and mitigate the weaknesses of each attribution structure.

The challenge behind revenue sharing in public transport is that the fairer an attribution model, the more complex and expensive it gets. The capital investment in changing systems (including hardware such as gate and turnstile systems) is significant in some contexts where interoperability has not been designed from the start. Integrated fare structures may also dilute incentives for stakeholders to innovate, as business risks fall on one actor and benefits are shared by all. A generally valid practice for globally acceptable revenue attribution for integrated public transport fares has not yet been found, and will likely never emerge. Public transport fare policy is largely a localised phenomenon given the broad range of socio-economic, spatial, political and infrastructural conditions that must be accounted for in the fare policy and resulting revenue-sharing models.

Revenue-sharing models for integrated, multimodal mobility services based on the integration of a variety of transport service providers offering an array of different products with vastly differing product attributes and price structures appear substantially more complex than revenue sharing among public transport operators. Additionally, the business cases and structures of transport service providers between the different subsectors of transport service provision are vast, which is likely resulting in heavily diverging interests. Revenue attribution models that could guarantee an acceptable distribution would likely be inefficient and expensive. Service providers' willingness to engage in such schemes is highly unlikely considering the already small profit margins of transport services.

Real-time payments and the evolution toward automated, instant settlement appear to provide useful solutions to the revenue allocation problem, as the need for revenue sharing subsequent to a journey becomes superfluous if mobility service providers pay transport service providers for the products they resell to a customer in real-time – instantly as the transport product is booked. This would allow for the provision of pay-as-you-go products across operators, with payment for the various legs of a journey integrated and billed to the customer by an intermediary mobility service provider.

Direct settlement between transport service providers and mobility service providers that resell the transport service in an integrated product indeed integrates the payment for various transport modes. At the same time however, it likely is unable to integrate the fares of the various operators and service providers into a meaningful, competitive fare structure of the type public transport authorities seek to achieve with their fare integration and revenue-sharing schemes. The system would allow the purchase with direct settlement but would stack the products of the various legs of a journey, and the cost billed by the respective operators, on top of one another. The price of a journey results from the accumulation of the prices of each leg. The lack of proper fare integration across operators may limit the business case of MaaS providers and the competitiveness of multimodal integration.

Resale of public transport services

For MaaS to deliver compelling choices and achieve success, it must be able to integrate a range of mobility services, including public transport. To that end, MaaS providers should be able to resell public transport tickets as part of their service offer. The opening of public transport tickets for resale by MaaS providers, however, has been a bone of contention since MaaS began to be established beyond the pilot phase. There are two points to be considered. The first is the opening of any or all ticket products for resale by third parties. The second is the offering of discounts or commissions on the sale of those tickets. MaaS providers need to extract value from somewhere in the ecosystem. If they can bring value in return – e.g. through the growth of public transport use – then that could justify beneficial pricing, but this case has yet to be proved.

The question of discounts, resale of tickets and subscriptions or commission is more difficult to answer and will ultimately come down to the context in each region and the ways in which public authorities use fare policies to deliver on public policy objectives.

Generally, public transport farebox revenues cover less than the full cost of providing services. Public transport is also often under-priced to keep it attractive compared to the private car. The difference in revenue and cost is usually subsidised by the state or regional government because public transport provides a public service as a means of improving equitable access. A common means of delivering subsidies to those who need them is through concession fares for certain groups in society (for example older people, school children), while those who can afford to, pay the full fare. Passes for regular users allow them a reduced per-trip cost.

A common concern is that offering discounted public transport rates to MaaS providers, particularly if they are targeting a well-to-do audience, risks implicitly subsidising MaaS providers. The fear is that the public transport authority could risk losing money on its profitable routes, while continuing to fund routes in poorer or low-density areas. This risk, however, could be counterbalanced by an increase in overall levels of public transport use, particularly at off-peak hours.

An alternative approach is for MaaS platforms to be offered discounts for bulk-buying tickets. The discounted bulk selling of public transport tickets to MaaS providers would guarantee a certain level of sales to the public transport operator. It would also to some extent mitigate the risk of platforms promoting less sustainable modes, as they would be incentivised to recover the costs of the public transport tickets. In this instance, although the MaaS provider would be securing a discount, they would also be carrying the entire revenue risk for those trips – the agreements would need to be carefully judged to ensure a fair distribution of risk. On the other hand, margins are already quite low and it is not clear what threshold of increased sales leads to overall benefits for the public transport operator. It also is not clear that public transport operators would derive many benefits if increased ticket sales led to more travel at peak hours where marginal gains are lower than at off peak hours.

If the decision is made to open the resale of tickets to MaaS providers, the question remains how to regulate that reselling, given that public transport fares are regulated. If the margins that the MaaS operators can make on the public transport tickets are likewise regulated, then that could lead to inefficiencies and miss the potential opportunity for dynamic pricing that MaaS could represent. On the other hand, if left unregulated, it could favour larger MaaS operators, who may be in a stronger negotiating position. In practice today though, most emerging MaaS service providers are small compared to incumbent public transport operators and are thus in a weaker negotiating position. The reselling decision will also require resources on the public transport authority's part to negotiate bilaterally with MaaS operators.

The ability to regulate public transport tickets extends to more than a revenue issue for public transport authorities – it is also a means of achieving policy objectives. For example, differentiated pricing is a policy measure available to public transport authorities to manage their network – for example, they can discourage network use at peak times through a "peak" fare. Equally, when trying to make the most of their available capacity, a reduced "off-peak" fare can be used as an incentive. Deeply discounting or offering free public transport for certain classes of users supports social policy objectives.

The importance of public transport fare policies in supporting, guiding and delivering on public policy outcomes suggests that public authorities should retain control of this lever (or a functional equivalent thereof) in the MaaS ecosystem. Public transport authorities and operators should be able to ensure that the contribution of fare policies to achieve sustainability or social objectives is preserved when MaaS providers resell or rebundle public transport services. A similar position is taken in the joint opinion of the association of European Metropolitan Transport Authorities (EMTA), Polis and the International Association of Public Transport stakeholders (UITP) (EMTA, Polis and UITP, 2021). In practice, this means that public transport authorities and operators should be able to negotiate fair and reasonable terms of sale and reuse of public transport services with MaaS providers such that they retain their ability to achieve policy goals. This will require specific competencies on the part of public transport authorities and operators as well as oversight to ensure that negotiated outcomes do not erode public policy outcomes. Given the rapidly evolving nature of the MaaS ecosystem, whatever resale arrangements agreed between public transport authorities and operators and MaaS providers should be periodically reassessed (via time-bound contracts or regulatory review milestones) to ensure that they do not prevent the future development of innovative ticketing agreements.

MaaS is too new, and not yet widely enough implemented, to be able to demonstrate that it can grow the user pool for public transport. However, collaborative and open approaches to micromobility have allowed authorities to work with private sector providers to develop the sector in line with public policy objectives. In combination with other strategic policy measures that disincentivise private car use, offering reduced rates on public transport tickets may prove to be the appropriate approach in the context of achieving policy goals, including improved resilience for the urban mobility system.

Ultimately, MaaS platforms should identify and be able to articulate the value they bring to the transport system. Public transport tickets should be made available, but the public transport authorities should be in a position to set the fair and reasonable resale price in negotiation with the MaaS platforms. The whole system should be monitored to ascertain whether it is contributing to the public policy goals; agreements should initially be short term. The public transport authorities should also be able to renegotiate ticket prices at suitable intervals to avoid being stranded with unfavourable terms.

Deficiencies of digital service markets

In digital service markets there are network effects. The consequence is that strategies of companies active in this field are often predatory and steered towards the gain of market share towards monopoly at all cost – with even profitability being a secondary objective over long periods. This also applies to digitalisation in mobility and is particularly problematic in this sector, as its footprint in the physical world is significantly larger than in other digitally mediated sectors (e.g. social media, content streaming, online retail, hotel bookings). One result of deficiencies of digital markets is the development of competing walled gardens, as described earlier. These vertically integrated, closed ecosystems with all functions in the control of one organisation manifest predatory strategies that lock in customers and sellers (= mobility service operators or MaaS providers) and tend towards mutually exclusive transport fleets. Rather than using digital technology to create meaningful market outcomes for citizens and cities by addressing underlying mobility market deficiencies, these models exacerbate networked market deficiencies. Actors employing walled garden strategies seek to control as many aspects and value activities of that closed ecosystem as possible, installing or exclusively integrating transport services that would only be available to customers of the respective walled garden ecosystem. Such strategies create lock-in for customers and sellers and establish mutually exclusive, competing, vertically integrated and closed transport ecosystems that are incompatible with the sustainable mobility goals of effective and efficient use of space, infrastructure, and vehicles.

Difficulty of commercially promoting sustainable mobility options

There is an inherent tension between market interests and sustainable mobility in the context of MaaS, since the modes that are most sustainable from a societal viewpoint (walking, cycling, and public transport) are either free or low-margin, subsidised modes and are thus poorly or not remunerative from a commercial perspective. The modes potentially yielding the most attractive margins for mobility service operators and thus increasing their financial interest in promoting these services are primarily car-based modes, like taxis, car sharing and rental cars.

Suboptimal MaaS market outcomes

MaaS development would be considered suboptimal if the concept promises to contribute to sustainability outcomes but fails to create a viable market. Or if the concept is unable to deliver these sustainability outcomes at all, potentially even deteriorating already achieved sustainable mobility objectives. A fragmented regulatory landscape leading to the development of bespoke MaaS schemes that are not interoperable or scalable beyond the local context is clearly suboptimal. Finally, if stakeholders cannot find a viable business model, this too would be a suboptimal development.

The suboptimal scenario, where MaaS as a concept proves beneficial for sustainable mobility but is unable to materialise at scale may be provoked by narrowly limited market entry rules for MaaS services. A monopolist MaaS player, be it a service produced by a single public or private sector service receiving a *de jure* (e.g. through a concession) or *de facto* (e.g. through market concentration) monopoly in a market, may be unable to reach the market segments that would provide greatest benefit if their mobility sourcing behaviour was less habitual and asset ownership based.

Public transport services provided by a strong and uncontested incumbent may, for example, enhance outcomes for its own customer base but may not be attractive to people whose trip patterns are not amenable to public transport or who may be sceptical about public transport. On the other hand, a quasi-monopolist commercial service may develop MaaS as a lifestyle product geared towards tech-savvy, affluent citizens. Both purely public and private monopolies may eventually hamper innovation and so will not be able to provide differentiated services that might be necessary to make the concept and its potential benefits accessible to a variety of market segments. This would be true especially for those stuck in habitual transport mode choice skewed towards the private automobile, which are the segments that yield greatest sustainability impact.

Another possible factor that may hamper the broad uptake of MaaS relates to its limited availability in rural and peripheral areas away from dense urban centres. It is these areas where car dependency is greatest. Density is an underlying driver for the efficiency of many transport services, as concentrated transport demand levels are necessary to achieve acceptable cost-effectiveness – let alone profitability for many services. For this reason, new mobility services (e.g. shared ride selling, sharing of transport assets) typically do not operate outside of dense urban centres. Another reason for successful deployments of MaaS in low-density environments may be lack of knowledge about the much more complex travel patterns in rural areas. Superposing urban-based mobility service and MaaS models to rural areas will likely not capture this complexity, or take into account the needs and characteristics of rural areas.

Fragmented, poorly aligned and incompatible local or regional MaaS frameworks are suboptimal if the objective is to seek broad scaling at the national or international level. While most daily travel is local, a significant share is interregional. If MaaS frameworks are inconsistent with each other or otherwise limit intercity travel and the use of MaaS services in other cities, scalability will be hard to achieve and may impact uptake of MaaS even in local contexts, as its usefulness for certain travellers is limited. This interoperability challenge is well known by public transport operators and, in some countries and regions, has led to unified ticketing and service frameworks (e.g. Japan and the Netherlands). Applying such regional interoperability frameworks to MaaS will help the market grow and deliver on its promise.

Another outcome of suboptimal MaaS development may materialise if market governance is unable to address natural incompatibilities between sustainable mobility objectives and commercial business interest. Three aspects of this issue are apparent. Sustainable modes offer little to no margins; alternative revenue streams for MaaS providers may negatively impact mobility behaviour; and enriched data as a basis for the competitive advantage of an efficient transport system may be distributed asymmetrically, or considered a tradeable good.

Certain forms of citizens' sustainable mobility behaviour is naturally at odds with business interests, as the sustainable modes (walking, cycling, public transport) are free or low-margin, subsidised modes, respectively. The modes potentially yielding margins for MaaS service providers, increasing their interest in promoting these modes, are primarily car-based (rental and shared cars, taxis and ride services). Out of commercial interest, MaaS services may lead to substitution of sustainable mobility behaviour with less sustainable behaviour due to greater monetisation opportunity of motorised services.

For profit, MaaS services may seek to increase and diversify their revenue. A potential effect of this may be the routing of customers along business locations of organisations paying the MaaS provider for this additional customer exposure, with the effect of potentially longer routes or inefficient mode choices for the customer. Such practices foster lack of transparency and are at odds with sustainable mobility outcomes.

Enriched data produced by MaaS services create meaningful insights into mobility demand and behaviour. These insights are valuable as they may provide competitive advantage to mobility operators and MaaS providers. These insights are, however, of value to the public sector as well to gain a holistic overview and regulate the transport system, allow for efficient adjustments of infrastructure and services, and take measures where outcomes do not align with policy goals. Commercial organisations may have an interest in withholding such insights from authorities, or may want to use the sale of these insights to the public sector as an additional stream of revenue. Such practices foster already existing data asymmetry and are at odds with sustainable mobility outcomes.

Allowing for flexibility and building confidence

It is unlikely that MaaS in any context will enter into operational existence fully formed. Regions in the vanguard of MaaS implementation should be looking to flexible pathways for implementation to account for the lack of long-term operational experience of MaaS. It should be noted that an evolutionary approach to market structures is not limited to new mobility solutions. As a starting point, it may be helpful to agree a minimum viable market configuration for the MaaS ecosystem and adopt a code of conduct among stakeholders, to allow time for MaaS markets and regulations to mature towards that base system. To this end, the Mass Alliance has specified elements that should be included in a local code of conduct in their MaaS Market Playbook (MaaS Alliance, 2021).

In Paris, a code of conduct was agreed between the city and scooter operators after the e-scooters first appeared on the streets. The code of conduct has since been replaced by licensed operators, with both the number of operators and the size of the scooter fleet now capped (*The Guardian*, 2019; *Financial Times,* 2020). Paris had already brought in other restrictions to manage safety and public space (*Financial Times*, 2020). However, there was also the suggestion that licensing was a good means to ensure a market size that allowed sufficient custom for the operators in it, after six previous e-scooter operators had already stopped functioning in Paris (*Wired*, 2019). The new licences have a two-year duration.

For MaaS in Belgium, a public-private, not-for-profit association has taken the lead in organising a collaborative approach to developing MaaS in the country through a Belgian MaaS Alliance. In the Flanders region, MaaS policy is being developed through the co-creation by stakeholders of a Flemish MaaS agreement framework that will provide consistency across the region, but allow for flexibility in how it is implemented (Vlaanderen is mobiliteit and openbare werken, n.d.). Here, the development of MaaS is being conducted under the Basic Accessibility Decree, rather than a specific legal framework for MaaS. The public transport authority is facilitating the co-creation process. The work will follow a phased approach to creating the principles for MaaS in Flanders, without looking to deliver the complete final MaaS model in one go. At the end of the current process to develop the agreement framework, a review period is planned to learn lessons and plan for a second cycle. In this way a structured, adaptive approach is being adopted.

In San Francisco, a proof of concept agreement (POCA) was created to manage the launching of shared mobility services. This was recognition of the potential benefit of shared mobility to complement the existing transport network, but equally of the need to have some form of permitting to manage public space (City and County of San Francisco Municipal Code, 2019; San Francisco Municipal Transportation Authority, 2019). The goal of the amendment was to “allow new shared mobility entrants a clear path for innovation on city streets, while ensuring the SFMTA has the regulatory tools needed to manage and evaluate their impacts on the City’s mobility goals, and alignment with the City’s Guiding Principles for Emerging Mobility” (San Francisco Municipal Transportation Authority, 2019). The duration of the POCA is limited to allow for evaluation. This can then be followed by the possibility of refining the service or developing either pilot or permit schemes depending on the results of the evaluation. The POCA can be cancelled at any time by the authority, and the possibility of levying fines on operators without a permit is open to the authority (San Francisco Municipal Transportation Authority, 2019). The POCA is capped at 12 months’ duration.

Necessary skill set for local and transport authorities to effectively govern multimodal mobility

With continuous technological advancement and the deployment of infrastructure, transport and mobility services employing new technologies, new mind sets and skill sets must enter the transport sector and the governance debate. Local and transport authorities, which have been concerned with the regulation of primarily physical activities, now see themselves confronted with questions raised regarding the digital dimension of mobility. Ineffective or reluctant addressing of these issues results in very physical deficiencies. Local and transport authorities will need to build and diversify their teams' skill sets to best manage the deployment of digitally enabled services and business models, and nurture the immense possibilities of a digitised mobility system. This upskilling should also address the ability of public authorities to develop and deploy innovative and digitally enabled governance mechanisms. The following describes an indicative list of recognitions or skills that may help local and transport authorities with these tasks.

A *certain degree of digital* – Authorities need team members that understand the powers and potential of digital technology as well as its limitations, pitfalls and problems. Authorities need to be able to relate these potentials and problems to the physical world in order to anticipate the necessary regulation. The regulation of routing algorithms provides a good example: authorities will not necessarily have to programme routing algorithms in-house, although some of them may choose to do so. But authorities will need to understand these algorithms, their principles and biases, and the effect those biases have in the real world.

More *data-driven and flexible decision making* – Authorities need team members that can interpret data insights and create meaningful recommendations for adjustments of infrastructures and transport services. Such data-driven adjustments should, to a certain degree, be implementable in a flexible manner and always be accompanied by data collection to allow for interpretation of the adjustment. This enables authorities to learn continuously and provides funded evidence for the public and political governance discussion.

A more commercial mind set – Authorities need team members that understand commercial interests, motivations and mind sets in order to collaborate with private sector players. Technology start-up organisations in particular may not necessarily have a mobility background are not always aware of transport market dependencies. Team members that understand private stakeholders and new entrants especially, and that can anticipate their business behaviour because they understand their rationale can become the link between traditionally planning-based authorities and the trial-based, iterative digital business community.

An *understanding for collaboration* – Authorities need to learn how to define policy and mobility goals as well as undesired outcomes in a way that allows the wider transport community to contribute their part to the archives. Through such a strategy of enablement, authorities can define the narrative of mobility without having to write the book all by themselves.

Issues and risks to be considered in MaaS data governance

There is no MaaS without data – or, more precisely, without data sharing among all MaaS stakeholders. Data and the knowledge derived from their collection, processing and analysis, has of course been a necessary component of the delivery of any mobility service. Providers have relied upon data regarding the location of static and moving assets; data regarding the scheduled or real-time operation of services; data regarding prices and payment clearing; data regarding access rights and customer profiles. What MaaS changes is the need to share this data among other actors in the broader mobility ecosystem in order to provide joined-up services for travellers. The ease that MaaS promises for travellers via a convenient user experience via a customer-facing user interface builds on a tremendously complex back-office exchange of sometimes sensitive information among different actors. Delivering MaaS will require an appropriate data governance framework that provides guidance as to how to manage these exchanges in a way that enables remunerative business models, provides a compelling experience for travellers, and maximises social welfare outcomes. This section outlines the main components to address.

Data are not ubiquitous: The potential bias of no data

Not everything of consequence for urban mobility produces data. While much of the discourse around digitally enabled mobility services centres on the large and often real-time stream of potentially MaaS-exploitable data they produce, much of what moves in cities does not produce such easily exploitable data streams. Insofar as these modes (walking, cycling and car driving) form the basis of overall trips in cities, this is an important blind spot. It may not weigh as heavily in the organisation of MaaS as these data do not concern commercial services, but it does matter in terms of monitoring the impacts of MaaS on overall mobility. Data-monitoring methods for these modes are based on observation, not on self-produced granular digital data. This difference should be accounted for where it may have an impact on the ability of public authorities to monitor overall system performance.

Governance frameworks help optimise data value creation

Data access and sharing is at the core of all three of the MaaS integration functions outlined earlier – informational, service interoperability, and financial transactions. Data are also essential for public authorities to monitor and ensure that the MaaS ecosystem is delivering on public policy outcomes. The uptake of MaaS predicates a market that is increasingly centred on data exchanges and their value. This value is best optimised when data-driven solutions are co-ordinated and framed within a coherent data governance framework. This framework is emerging but is unevenly specified and deployed across sectors, regions and urban contexts. Addressing data governance, developing and adopting data governance principles and adapting these as needed are all essential to the success of MaaS. The World Business Council for Sustainable Development (WBCSD) outlines five high-level domains that data governance must address (WBCSD, 2020): i) data collection and merging, ii) data standards, iii) data infrastructure, iv) governance and accountability, and v) use and analysis. Five overarching principles cover data governance issues relating to these domains (SuM4All, 2021):

1. Data sharing should enable all stakeholders to create and capture value.
2. Data sharing must be ethical, inclusive, and unbiased.
3. Data sharing should incorporate privacy by design.
4. Data sharing should embrace cyber security by design.
5. Data sharing should be adaptive and iterative.

These principles should be built by design into MaaS data governance frameworks and help frame the data value proposition for collaborative mobility (see Box 3).

Box 3. Key recommendations guiding policy making for data sharing in support of sustainable mobility

The *Sustainable Mobility: Policy Making for Data Sharing* specifies six key recommendations as a call to action for policy makers at all levels – municipal, regional, and national – to better frame data-sharing policies in support of sustainable mobility:

- *Adopt a collaborative approach for data sharing among diverse stakeholders* – Collaboration among policy makers, governments, citizens and civil society members, businesses and academia will require defining a common vision for sustainable urban mobility and how data sharing is expected to deliver these objectives. Corollaries of these requirements are the principles of purpose specification and data minimisation, which suggests that the minimum amount of data be collected toward explicitly stated purposes with the appropriate consent from parties that generate the data. This is especially valid for business-to-government (B2G) data transfer for regulation or planning purposes, and data from individual citizens.

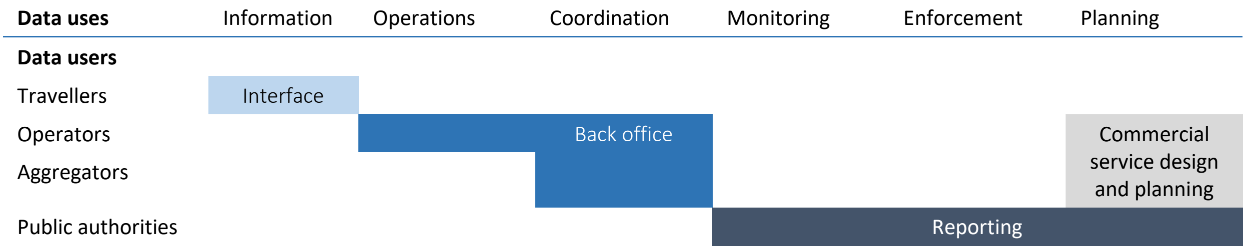
- *Commit to shared value across stakeholders to enable and accelerate* – Data sharing for a common vision leads to the creation of social, environmental and economic value that may be shared among all. Policy makers can help create a fair and competitive data-sharing ecosystem by considering the interests and varying capacities of each stakeholder.
- *Prioritise skill development and capacity building to increase competitiveness* – Governments should prioritise skills development in areas such as artificial intelligence, machine learning and cloud computing, which are necessary for advanced data processing and sharing capabilities. National policies, for example, should also account for disparate local contexts, and provide incentives to local governments to address any knowledge gaps to ensure successful implementation of national priorities.
- *Seek harmonisation across jurisdictions while allowing for customisation based on the local context* – Data-sharing models are often more effective when tailored and adapted to the local mobility system. Scaling and replication of data-sharing models are facilitated by overarching national or international architectures and harmonised data-sharing approaches that break down inter-organisational silos. For example, interdepartmental and intergovernmental cooperation overcome silos and improve interoperability and cost efficiency in areas such as data-sharing agreements, digital tools and platforms, and policy-making processes.
- *Establish trust frameworks as a foundation for implementing multi-stakeholder data sharing* – Governments can endorse and facilitate the development of trust frameworks – standardised legal and contractual agreements – to support effective collaboration among various stakeholders, and ensure that data sharing adheres to a common vision. Governments, through rule-making processes, can address common biases that may result in inequitable outcomes along gender, race, or age differences.
- *Embrace iterative, incremental and adaptive policy-making processes* – Continuous and proactive learning will allow policy makers to develop data-sharing models through demonstration projects, iterative experimentation and fail-fast approaches, and regulatory sandboxes. Starting small with priority policy objectives to understand types of data and means to access and process them can be a recipe for long-term success.

Source:(SuM4All, 2021).

Data, their value, and the functional domains of the data governance framework

Data have multiple producers and users in the MaaS ecosystem, and the uses to which these data are put differ across MaaS actors. Both of those factors – data users/producers and uses – have an impact on the data governance framework (Figure 11). This section discusses the key elements to be considered.

Figure 11. Data users and uses: Elements of the MaaS data governance framework



Interface

Travellers require information on the services they wish to use and purchase. This information is delivered through a user interface. Because the structure of the interface and the way in which the information it presents impacts the choices people make, the user interface forms one key component of the data governance framework. Elements to consider here are:

- Who owns or controls the interface(s)?
- How transparent are rankings and other information presented within the interface?
- How readily can multiple and competing interfaces draw on data from all operators in the mobility ecosystem?
- How well can users control their preferences within the interface or in their choice of interface?
- Is there a need for public intervention to align outcomes with public policy objectives (e.g. competition policy, priorities for use of public space, environmental and equity objectives)?

The back office and commercial service design and planning

Operators derive operational value from the data they produce and process. These data allow them to produce their services and typically covers routing, scheduling, dispatching, customer relations and fulfilment. Those are the core data components of MaaS service design because access to them allows for seamless service delivery across operators. For this reason, operators require access to analogous data that other operators produce and process, as do data aggregators whose business models are based on bundling these services for travellers. The back office domain largely involves communication among mobility service providers and data aggregators and processors. The key elements to consider here, in terms of the data governance framework, relate to data portability, data and protocol interoperability, and data sharing and reporting. Specifically, the data governance framework in support of MaaS should address the following:

- What provisions are made for customer data portability?
- What level of sharing is incentivised, compelled or agreed among actors?
- In what format are these data encoded and what level of compatibility exists among formats?
- What uses can shared data be put to and what uses should be prevented?
- Which mechanisms or processes are used to access and share data among MaaS ecosystem participants, and who owns or controls these?

Data portability

The strong dependency of digital service markets on data raises the risk of data lock-in for consumers (Cremer, de Montjoye, and Schweitzer, 2019). Large digital platforms or digital services that build vertically integrated "walled gardens" have sought to limit people's ability to access and transfer their data to other services and platforms, and may continue to do so. For this reason, data access and portability are one of the rights addressed in General Data Protection Regulation (GDPR) in the EU. The GDPR data portability formulation addresses the right of people to have access to their own data. In the context of digital service regulation, it may be worthwhile to address the possibility for people to transfer their data from one service operator to another. This facilitates switching and multi-homing and prevents the risk of anti-competitive data lock-in. As there is no natural incentive for any single operator to push for this, there is a clear role for public authorities to define minimum data portability requirements. These requirements should be limited to data about the data subject (owned data) but not to data inferred about the subject (which would fall under the data processor's purview). In the context of the MaaS ecosystem, the data-sharing requirements discussed below may be seen as a form of data portability where data related to a traveller is shared (subject to the data subject's consent) with all other relevant stakeholders, in order to enable efficient functioning of the MaaS ecosystem. This raises the issues of the latency of data portability (real-time versus periodic) and, crucially, the consent mechanism offered to data subjects.

Data sharing among market actors

Both operators and aggregators may derive value from better planning services developed from insights gained from shared data. A key element to consider is the extent to which sharing of operations and co-ordination data could allow competing rivals to improve their performance to the detriment of others. Operators and aggregators derive value from better targeting their services based on intelligence derived from analysing shared data, and planning and deploying (or adjusting) those services accordingly. This clearly increases value for travellers but also raises questions of competition among operators. The willingness to share essential business intelligence is low among operators who are, or perceive themselves to be, direct competitors for travellers. This is not necessarily a signal that public intervention is required – it should only be triggered by real and identified market failures – but perceived losses of market power will condition how actors engage in or block data-sharing initiatives. Nonetheless, there is a case to be made for developing a basic level of data sharing among operators that enables the MaaS ecosystem to function. At a minimum this data should include information on scheduling, availability, latency and location of services. These form the basic data "infrastructure" on which integrated MaaS offers can be built. Further data sharing is complicated by competing interests among market actors and tensions between market function, competitive interests and public policy objectives as described earlier with regard to deep integration and resale of mobility products. This arbitration is still under way, and thus MaaS regulations should allow for flexibility and experimentation in this domain.

Data platform access and governance

Operators offer their services to people via an app-enabled platform that may be operated either by one of the operators themselves, by a public authority, or by a dedicated third party. In all three cases, MaaS platforms raise the question of how platform access rules are set, who serves as the gatekeeper, and how to prevent anti-competitive behaviour.

Some actors develop their own vertically integrated platforms populated by their own or partner services. These "walled garden" models can deliver significant consumer value, as all services are tightly co-ordinated. However, the risk of anti-competitive behaviour is present, as is uncertainty regarding how well these platforms may be able or willing to contribute to broader policy outcomes. Enabling and supporting data reciprocity or quid-pro-quo models can offer a neutral pathway to broader sharing of data among market actors.

Platforms operated by public authorities ensure the integration of policy goals within the governance of the service but raise questions as to exclusionary behaviour in relation to new market entrants, or favouritism by public authorities with regard to publicly supported services. Clear and transparent platform access rules and trustable auditability of platform operations may mitigate some of these risks. Platforms operated by third parties may also avoid some of the risks encountered by publicly operated platforms, but require the same sort of transparent operating rules, auditability and accountability towards public authorities.

It is worth noting that while in the emerging platform economy it is typically the platform that benefits from a bargaining position stronger than that of the underlying service providers, in the current early stages of the MaaS market the situation is often the opposite due to the characteristics of the transport services market. A key question to address in this context is how to regulate platforms so that they mitigate rather than amplify the monopoly characteristics of the transport service market.

Data reporting to authorities

Mobility-related data collection, knowledge and insight are increasingly shifting away from the public sector and into the private sector. This shift implies a growing information asymmetry between those in charge of regulating mobility and public space, and those with access to actionable and relevant information.

That mobility operators naturally seek to protect the privacy-revealing data of their customers or commercially sensitive data regarding their operations is aligned with their business interests. This contrasts with a generalised move by public authorities to open their own data in order to stimulate new services and insights. It also raises questions regarding effective monitoring and regulation of shared public goods. For instance, mobility operators benefit from access to roads and curbs, but without data public authorities are limited in their ability to manage these spaces for the public good.

This has led to public authorities either purchasing data from commercial actors or compelling them to provide their data. Neither approach ultimately satisfies either party and yet “sell me your data” or “give me your data” largely comprise the only two data discovery options adopted by the public sector. Operators fear that overly broad data-sharing requirements on the part of public authorities may lead to privacy breaches or exposure of sensitive commercial data. While this risk is real, governments typically already collect and process sensitive data from individuals and companies, and have been able to mitigate the risks of data breaches with appropriate policies. Another concern is that public authorities may lack the knowledge or technical skills required to process the data for use in regulatory purposes. A final concern is that overreliance on digitally sourced data, because it is abundant and available, may lead to asymmetries between the regulatory treatment of “smart” versus other, less digital mobility services.

From a public policy perspective, data collected from mobility service providers can be useful for monitoring compliance and implementing enforcement of rules related to safety, regulated uses of public space, and other public policy objectives (e.g. competitive markets). These data can also be useful for planning purposes, helping authorities improve efficiency, equity and sustainability, and contributing to improving people’s welfare.

Governance of data sharing must address these functional outcomes as well as the capacity of stakeholders to abide by data-sharing rules. Where there is public value in collecting data, authorities need to establish frameworks that enable targeted data sharing that respects privacy and commercial sensitivities of both people and companies, while guaranteeing its cyber resilience. Because of the unique ability of governments to compel action, data-reporting mandates should be oriented to requiring the minimum amount of data necessary by default. Mandated data reporting from transport operators and MaaS providers to authorities should be purposeful and adapted to the regulatory tools and methods authorities deploy to meet their mandates (e.g. pricing, parking policy, urban access restrictions, speed management). Data reporting should be backed by mandating reporting requirements as part of licensing agreements or local code of conduct. Reporting requirements need to include rules relating to an appropriate level of aggregation, data handling, data retention periods and auditability, as well as data destruction protocols.

Addressing privacy

Rising concerns regarding the adequacy of regulations ensuring privacy have accompanied the exponential growth of digital mobility-related data, because these data typically comprise a geospatial component (ITF, 2015, 2016, 2019). Privacy risks from even fully anonymised or pseudonymised location data rest in the strong re-identification potential for geotagged data. Location is rarely directly linked to a unique individual – what is being tracked is a sensor linked to a platform. Many of these platforms (especially mobile handsets) are intimately linked to one person's activity patterns in time and space. Mobile handsets are almost always on, or near to, their owners and so the location data of these devices are highly revealing. Repetitive, predictable daily patterns of activity are a strong marker of identity. Trajectory-based and time-stamped location data are a potent quasi-identifier for a single person or persons within a single household – nearly as identifiable as a fingerprint. Even coarse-grained and imprecise trajectory data can be re-identified with relatively little effort. Location-based and trajectory data are difficult to fully and permanently de-identify.

The privacy risks posed by the difficult anonymisation of space-time trajectories suggests that the most robust data protection methods should be applied to location, trajectory and other high-dimensional personal data, and that smart mobility systems should adopt the principles of "privacy by design". These risks are addressed in the GDPR (Regulation (EU) 2016/679) insofar as location data are considered personal data in the context of the rule. Nonetheless, the evolution of data production, collection and processing and the risks posed via data sharing require a vigilant and evolutive stance with regard to privacy risks.

Purpose specification: Building the trust architecture for data sharing

Open frameworks typically generate more social value than closed frameworks, and this is generally true when it comes to data. For this reason, public authorities often seek to open up as much data as possible. They do this to spur value-enhancing uses of that data and to ensure that open data contributes to better outcomes. Recognising that there are privacy and commercial competiveness risks that may be impacted by overly broad release of publicly generated or collected data, it seems prudent that the cornerstone of an effective data governance policy is "as open as possible, as closed as necessary". Operationalising that principle into a data governance framework implies establishing the circumstances under which data access and sharing should be constrained – especially in cases where data sharing is compelled. This entails a mapping of desired outcomes to specific mechanisms for data sharing and reporting. Cases representing the highest risks require strict rules regarding the type, extent, and nature of data-sharing requirements and guidance regarding the aggregation, processing, access, retention and destruction of that data.

These rules help to establish a consensus regarding the uses to which shared data will be put while helping to underpin a robust trust architecture for data sharing. As noted, some operators may not trust authorities to safely manage and use disaggregated raw data. They prefer to handle processing tasks on their side and report aggregate information to authorities. Authorities may similarly not trust some operators to provide them with representative and accurate aggregate data, and ask them to share disaggregated raw data that the authorities then process. A third trust model exists where a neutral third party is entrusted to house and process data according to rules agreed by all. This third party could be a dedicated public agency or vetted commercial data processor.

All three of these models would benefit from having a clearer articulation of the circumstances under which data should be shared in order to reach which outcomes – an articulation that is rarely present in most contexts. Further, these different models rest on the ability of all partners to ascertain the trustworthiness of shared data. This means that robust auditing is required to reinforce that trust and to ensure that all stakeholders can be held responsible for breaching that trust. Auditing is rarely part of the frameworks for data sharing developed to date.

Recent changes in data science and new alternatives to data sharing provide new ways of extracting useable insight from raw data. In traditional data-sharing approaches, data are themselves transmitted from where they are collected and housed to a commercial partner or to a public agency – with all of the competition and privacy risks that might entail. This is because having the data in hand has been the best way to ensure the correctness, veracity, and trustworthiness of the analytical outputs based on them. However, rather than relying on transmitting data among parties, emerging approaches rely on exchange through trusted and vetted code – essentially transmitting code to the original data source and executing its analysis remotely. These algorithms run analytic operations on remotely held data and return trusted responses from that data. An example of this type of code-mediated trust mechanism is the SharedStreets Mobility Metrics code, which allows a public agency to ingest privacy-sensitive individual telemetry data from vehicles (in this case, from a MDS feed, see below) and aggregate it into meaningful metrics that are retained while the underlying raw data are erased or stored separately (SharedStreets, 2021).

Data semantics, syntaxes and data-sharing frameworks

Ensuring the back-office operation of MaaS and meeting regulatory reporting requirements call for the deployment of common data elements and languages. Specifying and enabling the use of common data access methods, semantics and syntaxes reduce the costs of co-ordinating and delivering MaaS services, and mitigates regulatory compliance burdens. Common formats have been the rule for analogue data reporting in the past, and the call for convergence around common reporting formats for mobility data is still very much relevant today. However, the rapid expansion of digitally enabled mobility services has led to a double burden. The many in-house data architectures and syntaxes are often not directly compatible with those of other operators, and they thus increase the cost of – and sometimes serve to block – the production of joined-up services. A second burden is placed on public authorities, which in pursuing their regulatory tasks face costs stemming from having to process data from various operators in incompatible formats or data syntaxes.

Data semantics in support of MaaS

Machine language requires a clear, consistent and unequivocal definition of terms and meanings. The first step in building interoperability and common reporting frameworks in a MaaS environment is to create and adhere to a common lexicon. While clarity on the semantic meaning of terms may be settled within each transport operator's own data architecture – for example, a public transport operator will have a consistent definition of what a bus stop is or what it means to say a passenger has commenced a trip – this may not be the case with other transport operators or with public authorities. In terms of new mobility operators where little harmonisation of data terms has taken place, multiple definitions may exist for such basic information as "is an asset available" or "has a trip ended". Even across public administrations, multiple definitions may exist for the same term (e.g. what comprises a parking violation). Greater interoperability across operators and aggregators, and improved regulatory oversight and enforcement, require convergence on these terms.

Mode-specific semantic models for exist for public transport data and serve as the basis for the syntaxes used to promote interoperability and reporting within those services. This is rarely the case for other services, and simply adapting the former to the latter may not prove an attractive option for new market entrants as it may not capture the specifics of their services. Developing and incentivising or requiring the use of such a lexicon will improve interoperability and remove uncertainty regarding whether public policy outcomes are being met. In order to achieve the broad uptake these semantic building blocks require, it seems appropriate that they be developed at the highest level, adopted by a wide number of actors, and deployed widely within and among countries. This argues for voluntary development and incentivised deployment via traditional standard-setting processes. This, however, will take time and there is no well-defined broad initiative to do this. In the meantime, market actors and authorities can incentivise adherence to a set of emerging semantical models that at least provide some form of convergence around the meaning of terms.

Three examples of these are the OSLO Mobility semantical model, the SAE Mobility Data Collaborative Data Sharing Glossary and Metrics for Shared Micromobility, and the Mobility Data Specifications proposed Metrics application programming interface (API).

The Open Standards for Linked Organisations (OSLO) semantical model was developed in the Flanders region of Belgium to address the need for common definitions and terms in support of the digital exchange of data in the domains of contact information management, localisation and public services (Van Roy, 2020; "Flanders Dept. of Mobility and Public Works", 2021). The mobility component of the OSLO semantic model establishes a lexicon referring to traveller information, trip information, booking actions, network description, service supply on the part of operators, and information relating to licences to operate.

SAE International (a US industry-based standard-setting body, formerly the Society of Automotive Engineers) developed its Data Sharing Glossary and Metrics for Shared Micromobility (MDC, 2021). This glossary is composed of a standardised set of definitions and methodologies covering commonly used terms and indicators. These terms include "non-operational vehicle" or "maximum average number of vehicles available in a given territory". Disambiguation of these and other terms helps deliver more consistent reporting and monitoring of these services and improves interoperability among operators.

Another, similar approach is being built into the forthcoming version of the Mobility Data Specification (MDS 1.1.0, described below). The MDS Metrics application programming interface (API) sets out standard definitions and parameters for calculating commonly used metrics based on MDS data (OMF, 2021a).

Data syntaxes in support of MaaS

Data syntaxes deployed in support of MaaS provide the structure in which the building blocks of language are organised to communicate meaning and to trigger action. Again, there is little room for interpretation in machine language. Therefore, specifying a data syntax that enables communication, or finding an efficient way to translate meaning from one syntax to another, is a core concern in the deployment of MaaS.

At present, there is no broadly accepted data syntax on which to build MaaS applications, or to convey information from mobility service providers to authorities. This hampers the uptake of MaaS. It may also give rise to asymmetries in power within the market if those standards that are proposed, or imposed, favour certain operators over others, whether by design or in practice. For this reason, there has been a generalised call for the deployment of open and mode-agnostic data syntaxes.

The public transport industry has developed data syntaxes that enable interoperability among public transport operators within and between regions and countries. In Europe, these include: NeTex, a standard for sharing public transport schedules and related data; SIRI, syntax for exchanging data on planned, current (real-time) and projected public transport system performance; and Transmodel, a reference data model that enables data sharing relating to passenger transport service operation (planning, operation and information). Globally, the General Transit Feed Specification (GTFS) is a light-touch syntax designed to enable the outward sharing of data related to scheduled or real-time public transport operations. GTFS, unlike NeTex, SIRI and Transmodel, was designed solely to help share information about the state of services and not to support operational linkages among operators.

Public transport-oriented syntaxes were not designed to cover the broad range of stakeholders within the MaaS ecosystem or to support operational linkages among them. Other service providers have adopted bespoke standards that enable them to share data regarding their own services. The General Bike Feed Specification (GBFS) is one example that has had success among docked and dockless micromobility operators and has become a core part of the MDS (see below).

Both private sector companies and public authorities have proposed open MaaS platform data architectures to spur the development of MaaS. A consortium in the Netherlands has developed a MaaS API – the Transport Operator to Mobility Provider API (TOMP-API) (TOMP-API, 2021a, 2021b). As part of a co-ordinated effort to trial seven different MaaS pilots, the Netherlands Government convened a working group to develop a common API framework for data sharing among transport and MaaS service providers. The TOMP-API standardises the interconnection between MaaS aggregators and transport operators, taking into account the entirety of travellers' intermodal journeys. It harmonises MaaS platform access across the full range of functionalities: identification, registration and on-boarding, trip planning, booking, trip execution, payment, support, asset information and other optional functionalities.

The need to connect disparate services and stakeholders in order to deliver MaaS may also give rise to commercial stakeholders who take on the role of providing MaaS platform architecture alongside either bespoke data connection interfaces or standardised APIs – or a mix of the two. One revenue model for these white label data platforms is to extract commissions from operators or travellers, or both. It is not clear, however, if these models are viable given the tight margins that characterise urban transport markets. Another model is to use the MaaS offer to attract and retain people in a broader application environment – "a super-App" – and generate revenue from more remunerative services, like banking or tourism services.

Data-reporting syntaxes and protocols

As with data syntaxes supporting the operational aspects of MaaS, there is no single or widely deployed data syntax for reporting relevant data from all mobility service providers to public authorities. Public transport authorities may require data reporting from public transport operators in one format; taxi and ride-sourcing oversight bodies may require reporting from operators in a different format; parking authorities in another format; and agencies in charge of shared micromobility in still another format. These different formats may include analogue and digital elements, and may be only partially composed of machine-readable data, if at all.

One solution is to combine all of these data within a common database environment – a "data lake" – and create data extraction routines and methods that process disparate data and extract useable insights. In this case, the heavy lifting is on the side of the data lake "owner" – in most cases a public agency. This processing has a cost and may involve contracting out data-processing services to a third party or investing in in-house capacity.

Another solution is to incentivise or require all mobility operators to conform to a data standard when reporting data to authorities. An example of this approach currently used by many authorities in regulating shared micromobility services is the MDS.

The Mobility Data Specification is a data standard and API specification currently configured for shared micromobility services (OMF, 2021b). Ultimately, MDS could be extended to all mobility service providers. MDS was developed to facilitate two-way communication from regulated entities to a regulator and from the regulator to regulated entities. The specification is a way to implement data sharing, monitoring and communication of regulatory intent for public authorities and mobility service providers. Public authorities often require MDS to be used in return for receiving operating approval.

At present, MDS comprises three distinct components: the provider API, the agency API and the policy API. Mobility service operators implement the provider API. It enables the exchange of data and operational information that the public authority may request in order to monitor compliance, adjust licensing terms, or plan on the basis of past activity. The agency API is implemented by regulatory agencies. It is a gateway that allows service providers to submit information to authorities regarding real-time operations and service delivery and enables agencies to dynamically manage public rights-of-way. The policy API is implemented by regulatory agencies and allows rules and regulations to be communicated in machine-readable formats that are directly ingested into mobility service providers' back-office systems. Arguably, this is the most innovative feature of MDS from a public policy perspective. A number of additions are being discussed for the next release of MDS (v.1.1.0.) including APIs that improve the ability for authorities to specify their data reporting needs and formats and reduce privacy risks. These include data aggregation APIs for reporting or for tracking aggregate trip-related data relative to geofenced areas and an API for consistently handling administrative boundaries.

Privacy concerns have been raised regarding the specific formulation of MDS. These relate especially to the detail and granularity of data collected (especially the frequent reporting of individual vehicle trip telemetry data) and associated risks for individual privacy and commercial sensitivity. These tensions are indicative of the greater challenge of ensuring that privacy risks are not exacerbated by the design of regulatory frameworks for smart mobility systems. The Open Mobility Foundation (OMF) has issued a privacy guide to help authorities implement MDS though it is largely focused on the US context (OMF, 2020).

Privacy concerns have contributed to the development of an alternative new mobility data specification that integrates strong GDPR-compliant rules by default. The CDS-M (City Data Standard – Mobility) has been pioneered in the Netherlands (CDS-M, 2021). It is functionally related to the TOMP-API but targets data exchanges between mobility service providers and public authorities. It is designed both to be a standard and to define protocols on data processing and storage. This standard seeks to deploy a set of functionalities similar to MDS, but extending beyond micromobility and accounting for the European data protection framework. CDS-M addresses three public authority requirements (CDS-M, 2021):

- *planning:* enabling cities to better manage public spaces for the adoption and use of multimodal transport
- *policy:* enabling transport operators to have a clear understanding of a city's policies for use of its infrastructure
- *enforcement:* enabling cities to ensure a high level of service by transport operators within a city's boundaries through policy enforcement.

The working group piloting the design of CDS-M is comprised of public authorities, MaaS stakeholders, transport service operators and experts. It liaises and co-operates with other standard-setting organisations, including the European Committee for Standardization (CEN) and the Open Mobility Foundation.

Supranational and national data-sharing frameworks

MaaS-specific data-sharing frameworks have been established, mainly within Europe. The European Union has passed a delegated act supplementing Directive 2010/40/EU on the provision of EU-wide multimodal travel information services, requiring members to put in place open data frameworks for multimodal trip data (EU Delegated Act 2017/1926). The act calls for EU-wide multimodal travel information services (MMTIS), which comprise standardised traffic and travel data for all mobility providers. These data are to be centralised through National Access Points (NAPs) to ensure uniform and widespread access and use of MMTIS data. The act does not cover open booking or cross-platform payment options.

Table 8. Required data-reporting elements for operators providing passenger transport services in Finland

The identity of the service provider, commercial registration number and contact information that a service user can use.
Data regarding the spatial coverage of the service.
Information on payment options.
Information related to the accessibility of the service to those with mobility or other impairments.
Machine-readable information regarding scheduled service operation and spatially-referenced route information.
The location of scheduled traffic stops, stations, terminals with related timetable information.
The period(s) for which the service or timetable information is valid.
For non-scheduled services and for any potential service provider, geospatial information on predetermined stops, stations, terminals, etc.
For non-scheduled or on-demand services, information on the times the services are available.
Information on how to book or hail the services(s) with a link to the booking engine if applicable.
Information on the price of the service including the breakdown into both static and dynamic (e.g. time- or distance-based) fare components, including discounts. This information should allow for cross-service comparison (e.g. for peak hour use).
Dynamic price information and information on available capacity, or a link to the service from which this information is available.
Information regarding restrictions, conditions, extra fees or policies or available options (e.g. regarding baggage transport, policies regarding animals, carriage of children, work stoppages, etc.).
Real time trip planning and *en route* data or a link to a service making this information available.
For non-scheduled services, map-based display of the location of available and/or booked vehicles or a link to the service from which the information is available.
Estimates of significant delays or cancellations in services as soon as they are available to service providers.
A link to the web site or other electronic service of the service provider.

The European Union has launched a consultation with a view to revising the directive: the current structure and scope of the regulation does not adequately address EU-wide data-sharing concerns; the focus has been more on data-enabling services than on deployment of the services themselves (EU Ref. Ares(2020)5341571). Specifically, the revision will go beyond simply specifying data access channels. It will address the availability of mobility data and its existence in a broadly useable and easily shared machine-readable format. The revision will also address co-operation and data-sharing frameworks for automated driving and MaaS.

Finland and France have both recently enacted ambitious data-sharing requirements in their national transport legislation, which meet the requirement of the delegated act and address the intent of the directive's revision. Finland, in its recent reform of the National Transport Code (NTC), lays the groundwork for data sharing in support of a national MaaS ecosystem (Table 8). Rather than focusing on data structure, the NTC addresses data availability and usability. The code calls for transport service providers and regulated entities to establish an open, easily accessible, and useable digital channel delivering a common set of data items. These provisions are meant to create an open and level playing field where both small and large operators can more seamlessly co-ordinate or link their services and create new innovative options or applications. Shared data items must include those outlined in Table 8 (Finnish Ministry of Transport, 2019).

The National Mobility Law in France (*Loi d'orientation des mobilités* – 24 December 2019) sets out requirements regarding data sharing in support of mobility as a service. The law and its application decree of 28 December 2020 specify data elements that must be openly shared in machine-readable format and accessible to the public, to public authorities and to private sector firms (see Table 9).

Table 9. Required data-reporting elements for operators providing scheduled or free-floating passenger transport services in France

Static data relative to trips and transport service traffic allowing destination search, route discovery, calculation of itineraries, fare requests and trip-planning information.
Dynamic data relative to services and traffic conditions for transport services allowing discovery of schedules, calculation of estimated time of departure and arrival, and accounting for service disruptions.
Historic and statistical data regarding the provision of transport services and traffic.
Static, dynamic and historical/statistical data regarding vehicle-sharing services (car sharing and fixed or free-floating light individual mobility devices such as bicycles and push scooters).
Data relative to public electric vehicle recharging infrastructure including wattage, price, payment options, physical accessibility, availability and vehicle size access restrictions.
Data enabling the access and use of peer-to-peer carpooling services including availability, pickup and drop off points, provisional schedule and cost.
Some data relating to the localisation of railroad level crossings.
Data relating to the physical accessibility for paratransit services offering public transport for people with mobility challenges.

These data-sharing provisions apply to all public transport operators and public or private mobility operators offering shared vehicle services. This includes shared micromobility operators but does not include taxi or ride-sourcing services because of the different legal status of these services. That means all mobility service operators will be able to develop their own MaaS services and applications on the basis of this data, including ride-sourcing and taxi service operators. But ride-sourcing and taxi operators face no reciprocal requirement to open their data to other actors in the mobility ecosystem. This creates an asymmetry in data access among market players and may potentially serve to favour walled garden MaaS services developed by ride-sourcing operators. The law is silent for now on what form these data should take and whether common and shared data syntaxes will be required.

Other data-sharing frameworks have been developed outside the scope of national laws. Germany, for instance, plans to develop a concept of decentralised, networked mobility platforms under the aegis of the National Platform Future of Mobility (NPM). On this basis, a comprehensive mobility data network is to be created, which will be shared by private and public actors. Germany has also developed a data service called mCLOUD, which serves as a data repository for open data from public and private sources.

The Netherlands has developed comprehensive and uniform guidance regarding data sharing in support of MaaS. The Netherlands Government has initiated a co-ordinated series of seven MaaS pilots in order to test and learn from various configurations and use cases of MaaS (DMI, 2021). One of the core objectives of the pilots was to explore how to rapidly scale up adoption of MaaS by travellers and operators. Each of the trials tests a different use case (e.g. commuting, cross-border mobility, improved accessibility to specific destinations; the trials are also deployed at different scales, from neighbourhood to regions). The national government allocated an envelope of EUR 20 million to cover the initial costs of the pilots in return for specified conditions for participation and outputs to be delivered. One of those was the condition that the pilots facilitate data sharing and co-operation among stakeholders. This aspiration was translated into a set of guiding principles:

- adoption of a common definition of MaaS, semantic lexicon and definitions
- reciprocal and obligatory data sharing
- use of a common open data-sharing standard (TOMP-API)
- an open MaaS ecosystem
- participation in a knowledge-sharing and learning environment common to all trials
- non-discrimination and adherence to privacy and security imperatives.

In addition to the data-sharing required in the uptake of the common TOMP-API, the learning environment requirement means that operators and MaaS service providers must also provide anonymised and aggregated data to enable research and policy-relevant knowledge creation. The Netherlands Government has designated an independent research organization – TNO – to receive and process this data and facilitate establishment of the knowledge base for MaaS trials.

Local authority mobility data governance frameworks

Local MaaS-specific data governance frameworks have essentially been trialled in Europe where there is no settled data governance model for the MaaS ecosystem reflecting the diversity of business models, platform governance approaches or local contexts. This means that what can be observed today is not necessarily how these frameworks will look as they mature and if MaaS markets scale up or as they develop outside Europe.

Most cities already have data-sharing frameworks in place for public transport. This is because in most cases local authorities not only license operations but subsidise services as well – and therefore need to monitor performance and delivery on public service obligations. Many cities also have taxi-activity reporting requirements; this is the case because taxi markets are typically regulated and this reporting allows authorities to ascertain whether outcomes are being delivered.

The arrival of shared mobility services and ride-sourcing has highlighted a gap in local reporting frameworks. While this gap is apparent across many new mobility services, closing it has disproportionately focused on data reporting from shared micromobility operators. This is probably because the impacts of these services were felt most acutely in public space and because no existing or analogous data-reporting framework existed. The focus on shared micromobility data reporting requirements also likely has to do with these modes producing digital data that could offer policy-relevant insights. According to a recent survey (Polis, 2021), public authorities were motivated to put in place data-sharing requirements in order to monitor developments, to develop regulations, and to manage public space. Most of the public authority respondents indicated they were receiving some information from shared micromobility operators. More than half of the survey respondents indicated that data-reporting arrangements were stipulated in the rules, requirements or contractual/licensing agreements governing the services. Most of the survey respondents receiving data indicated that use of some form of the MDS was either encouraged or required. The kind of emerging practice revealed in the Polis survey is important because it highlights public authorities' need to ensure that appropriate data-reporting frameworks are in place for emerging modes. Efficiently meeting these needs across the entire spectrum of mobility service providers is nevertheless challenging.

Some cities are establishing rules relating to data sharing among MaaS and transport service providers. In some cases, these build on national legislation (Finland, France) or on trials and initiatives (Netherlands, Germany). In France, some cities are putting in place data lakes (Lyon, the Île-de-France region) in order to co-house all mobility-relevant data collected or reported to public authorities. This kind of data centralisation facilitates the public authority's monitoring, enforcing and planning. In both cases, the public transport authority is the data lake "owner" and in both instances there is recognition that their role should be expanded to that of a "mobility authority" acting as an effective co-ordinator of the entire mobility offer within the region. The move to centralise and manage data reporting from all mobility operators is one of the essential functions of shifting beyond public transport only. However, this move requires a different and adapted regulatory framework, not just for data governance but also for transport governance.

Helsinki is a good example of how national frameworks for data sharing are transcribed to the local level. As already noted, the National Transport Services Act of Finland which revised the National Transport Code was rewritten to address what data should be shared and how. The sharing of scheduled service timetables, routes, stops and fares was part of the data-sharing requirements set out in the Transport Services Act (though the law was mute on what data specification to use). The law has been applied to operations in the Helsinki region, including those of the principal public transport operator. Though interoperability of ticketing and payment systems was also specified in the law, the public transport operator resisted over concerns regarding loss of the customer relationship with its clients. Under pressure, the operator relented and allowed access to ticketing solutions but only for single use tickets. This, alongside the difficult negotiations with the PTA on fair commercial terms, undercut the viability of MaaS providers' business models, which are designed to extract value from bundling public transport subscriptions and other mobility services. The law specified broad access to ticketing systems and all subscription options. However, friction and resistance from the dominant public transport operator has proved to be a barrier – even though the law explicitly noted that MaaS providers can access season tickets on behalf of their customers. Part of the difficulty in establishing the data-sharing framework was linked to insufficient specification of the form data sharing should take and the failure to link incentives or market access/operating conditions to that data sharing (Audouin and Finger, 2019, 2018; CEREMA, 2019; TNO, 2021).

Several MaaS initiatives have built on bespoke data-sharing platforms to support the MaaS ecosystem. These may be operated as turnkey, white label products by third party providers on behalf of different stakeholders. For example, this model is used to operate on behalf of the public transport operator in Berlin and Munich, on behalf of a consortia of authorities and public transport operators in the Skane region of Sweden, and on behalf of the public transport authority in the Ile de France region, and the city government itself in the case of Stockholm.

Most of these implementations involve some degree of operational control and vetting of services onboarded by the controlling or contracting agency. This allows the agency or authority to ensure that MaaS platform rules and operations are aligned with overall policy objectives. Nonetheless, effective control of the platform by a public transport operator – even if it is understandable in terms of the centrality of public transport in structuring the MaaS offer – raises issues with respect to how well other mobility operators trust that their interests will be accounted for and protected. In Vienna, the public transport operator and authority sought to address concern over potential platform access conflicts by creating a special entity that is operationally and functionally separated from the public transport operator. Upstream, the jointly owned public company (51% owned by the public transport operator and 49% by the city infrastructure agency) operates as a privately run company. Though the public transport operator is still present in the ownership structure, the company's rules of operation, reporting requirements and audit framework ensure its independence. The upstream platform (built on a set of bespoke APIs) provides an open interface for all MaaS and transport service providers, so they can connect and share information with other MaaS actors.

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Annex A. List of participants at ITF-WBCSD virtual events

Future Urban Mobility: Trends, Vulnerabilities and Resilience
29 May 2020

Steven AHLIG, Siemens

Yuichi AOYAMA, Honda Motor Company

Juraj ATLAS, Mileus

Alexandre BELIN, BNP Paribas

Robert BICHSEL, Siemens

Diego CANALES, Populus

Kiron CHATERJEE, University of West England

Aurelien COTTET, Transdev

Philippe CRIST, International Transport Forum (ITF)

Michele DAVIDE CIPULLO, Arval

Thomas DELOISON, World Business Council for Sustainable Development (WBCSD)

Pierre- François MARTEAU, BCG Mobility Practice

Luc GARGUET-DUPORT, Renault-Nissan-Mitsubishi

Sylvain HAON, UITP

Joel HAZAN, BCG Mobility Practice

Stephan HERBST, Toyota Motor Corporation

Sampo HIETANEN, MaaS Global

Jens HOFFMANN, Volkswagen AG

Paulo HUMANES, PTV

Asuka ITO, ITF

Philippe KAHN, Arval BNP Paribas Group

Piia KARJALAINEN, MaaS Alliance

Jari KAUPPILA, International Transport Forum (ITF)

Keiichi KITAHARA, Renault-Nissan-Mitsubishi

Kazunori KOJIMA, Toyota Motor Corporation

Takayuki KUSAJIMA, Toyota Motor Corporation

David LAINE, Trafi

Martin LEFRANCQ, Bruxelles Mobilité

Sebastien MARINOT, BNP Paribas

Irene MARTINETTI, World Business Council for Sustainable Development (WBCSD)

Luis MARTINEZ, International Transport Forum(ITF)

Lu PATRICK, Renault-Nissan-Mitsubishi

Ronan PERRIER, Arval BNP Paribas Group

Stefano PORRO, Pirelli

Zuzana PÚČIKOVÁ, Uber

Marième ROCCHI, BNP Paribas

Daniel SASCHA-ROTH, Volkswagen AG

Hirohiko SHIGETA, Japanese Ministry of Land Infrastructure Transport and Tourism

Jakob SPRANGER, Toyota Motor Corporation

Takashi TOGAME, Sony

Karen VANCLUYSEN, Polis

Stijn VERNAILLEN, Antwerp

Thomas WOLF, Hacon

Mobility as a Service: Resiliency as a Service
5 June 2020

Yuichi AOYAMA, Honda Motor Company

Alexandre BELIN, BNP Paribas

Robert BICHSEL, Siemens

Michael BUNCE, Allianz

Diego CANALES, Populus

Thibault CASTAGNE, Vianova

Kiron CHATERJEE, University of West England

Jean COLDEFY, Transdev

Aurelien COTTET, Transdev

Philippe CRIST, International Transport Forum (ITF)

James DATSON, TS Catapult, United Kingdom

Michele CIPULLO, Arval BNP Paribas Group

Juliette DE MICHEO CARRILLO-ALBORNOZ, Madrid

Marijke DE ROECK, Antwerp

Thomas DELOISON, World Business Council for Sustainable Development (WBCSD)

Anina DUBELI, Switzerland - BAV

Ulrich EDELMANN, Moovel

Luc GARGUET-DUPORT Renault-Nissan-Mitsubishi

Tom GEERTS, deLijn

Joel HAZAN, BCG Mobility Practice

Stephan HERBST, Toyota Motor Corporation

Jens HOFFMANN, Volkswagen AG

Paulo HUMANES, PTV

Haruo ISHIDA, University of Tsukuba

Asuka ITO, ITF

Maria KAMARGIANNI, University College London

Piia KARJALAINEN, MaaS Alliance

Jari KAUPPILA, ITF

Pauline KEE, Renault-Nissan-Mitsubishi

Michael KIESLINGER, Fluidtime

Keiichi KITAHARA, Renault-Nissan-Mitsubishi

Makoto KOIKE, Sony

Kazunori KOJIMA, Toyota Motor Corporation

Takayuki KUSAJIMA, Toyota Motor Corporation

David LAINE, Trafi

James LANCASTER, EHI

Martin LEFRANCQ, Bruxelles Mobilité

Sam LI, Manchester

Irene MARTINETTI, World Business Council for Sustainable Development (WBCSD)

Akihiro MATSUDA, Japanese Ministry of Economy, Trade and Industry

Orla Therese MCCARTHY ,ITF

Vasco MORA, Lisbon

Corinne MULLEY, University of Sydney

Kate PANGBOURNE, University of Leeds

Laura PAPET, PMP Conseil

Lu PATRICK, Renault-Nissan-Mitsubishi

Ronan PERRIER, Arval BNP Paribas Group

Gabriel PLASSAT, ADEME

Stefano PORRO, Pirelli

Zuzana PÚČIKOVÁ, Uber

Marième ROCCHI, BNP Paribas

Karri SALMINEN, CGI

Ida SCHAUMAN, MaaS Global

Hirohiko SHIGETA, Japanese Ministry or Land Infrastructure Transport and Tourism

Göran SMITH, University of Sydney

Jakob SPRANGER, Toyota Motor Corporation

Buonanno STÉPHANE, CGI

Takashi TOGAME, Sony

Karen VANCLUYSEN, Polis

Stijn VERNAILLEN, Antwerp

MaaS Changes in Behaviour
19 June 2020

Yuichi AOYAMA, Honda Motor Company

Sergio Fernández BALAGUER, Madrid

Graham BANKS, Manchester

Alexandre BELIN, BNP Paribas

Diego CANALES, Populus

Philippe CRIST, International Transport Forum (ITF)

Thomas DELOISON, World Business Council for Sustainable Development (WBCSD)

Ulrich EDELMANN, Moovel

Luc GARGUET-DUPORT, Renault-Nissan-Mitsubishi

Jens HOFFMANN, Volkswagen AG

Helen HUMBLE, Manchester

Asuka ITO, ITF

Maria KAMARGIANNI, University Colleague London

Piia KARJALAINEN, MaaS Alliance

Pauline KEE, Renault-Nissan-Mitsubishi

Michael KIESLINGER, Fluidtime

Lucie KIRSTEIN, ITF

Kazunori KOJIMA, Toyota Motor Corporation

Sam LI, Manchester

Markus LIECHTI, BAV

Irene MARTINETTI, World Business Council for Sustainable Development (WBCSD)

Vasco MORA, Lisbon

Corinne MULLEY, University of Sydney

Kate PANGBOURNE, University of Leeds

Laura PAPET, PMP Conseil

Lu PATRICK, Renault-Nissan-Mitsubishi

Caroline PONAL, BNP Paribas

Stefano PORRO, Pirelli

Zuzana PÚČIKOVÁ, Uber

Marième ROCCHI, BNP Paribas

Jakob SPRANGER, Toyota Motor Corporation

Buonanno STÉPHANE, CGI

Takashi TOGAME, Sony

Karen VANCLUYSEN, Polis

Menno VANDERLINDEN, Commotionsquare

MaaS Governance
29 June 2020

Yuichi AOYAMA, Honda Motor Company

Bon BAKERMANS, Netherlands

Sergio Fernández BALAGUER, Madrid

Graham BANKS, Manchester

Alexandre BELIN, BNP Paribas

Antoine BODIN, BNP Paribas

Diego CANALES, Populus

Thibault CASTAGNE, Vianova

Azarel CHAMORRO, Tokyo Institute of Technology

Sébastien CHARBONNEL, BNP Paribas

Jean COLDEFY, ATEC ITS-France

Aurelien COTTET, Transdev

Philippe CRIST, International Transport Forum (ITF)

Michele DAVIDE CIPULLO, Arval

Aiko DE MOL, SPF Mobilité

Thomas DELOISON, World Business Council for Sustainable Development (WBCSD)

Anina DUBELI, BAV

Ulrich EDELMANN, Moovel

Michael FISCHER, Greater Paris Metropolitan region

Luc GARGUET-DUPORT, Renault-Nissan-Mitsubishi

Tom GEERTS, Delijn - Region of Flanders

Stephan HERBST, Toyota Motor Corporation

Sampo HIETANEN, MaaS Global

Jens HOFFMANN, Volkswagen AG

Paulo HUMANES, PTV

Asuka ITO, ITF

Phillippe KAHN, Arval BNP Paribas Group

Nicola KANE, Manchester

Piia KARJALAINEN, MaaS Alliance

Michael KIESLINGER, Fluidtime

Lucie KIRSTEIN, ITF

Kazunori KOJIMA, Toyota Motor Corporation

Martin LEFRANCQ, Bruxelles Mobilité

Sam LI, Manchester

Irene MARTINETTI, World Business Council for Sustainable Development (WBCSD)

Sami MIKONNEN, CGI

Eric MINK, Netherlands

Ruud MOLLEMA, ICTU

Vasco MORA, Lisbon

Corinne MULLEY, University of Sydney

Gregor OCHSENBEIN, Swiss DETEC

Kate PANGBOURNE, University of Leeds

Laura PAPET, PMP Conseil

Lu PATRICK, Renault-Nissan-Mitsubishi

Gregor-Alexander PETRI, Fluidtime

Caroline PONAL, BNP Paribas

Stefano PORRO, Pirelli

Zuzana PÚČIKOVÁ, Uber

Marième ROCCHI, BNP Paribas

Buonanno STÉPHANE, CGI

Johanna TASKINEN, Kyyti

Takashi TOGAME, Sony

Karen VANCLUYSEN, Polis

Stijn VERNAILLEN, Antwerp

Carcel YANN, CGI

ITF-WBCSD Conversation of MaaS Opportunities and Challenges in Japan September 25, 2020

Alexandre BELIN, BNP Paribas

Azarel CHAMORRO, Cities Forum

Philippe CRIST, International Transport Forum (ITF)

Thomas DELOISON, World Business Council for Sustainable Development (WBCSD)

Luc GARGUET-DUPORT, Renault-Nissan-Mitsubishi

Stephan HERBST, Toyota Motor Corporation

Sampo HIETANEN, MaaS Global Ltd

Haruo ISHIDA, Tsukuba University

Shinsuke ITO, rimOnO corporation

Asuka ITO, ITF

Masafumi KAWASAKI, World Economic Forum, Centre for the Fourth Industrial Revolution

Kazunori KOJIMA, Toyota Motor Corporation

Takayuki KUSAJIMA, Toyota Motor Corporation

Irene MARTINETTI, World Business Council for Sustainable Development (WBCSD)

Haru MIYADAI, Institute for International Economic Studies

Itsuki NODA, National Institute of Advanced Industrial Science and Technology

Lu PATRICK, Renault-Nissan-Mitsubishi

Stefano PORRO, Pirelli

Jakob SPRANGER, Toyota Motor Corporation

ITF-WBCSD Conversation of MaaS Opportunities and Challenges in Europe
28 September 2020

Alexandre BELIN, BNP Paribas

Damain BROWN, Trafi

Boyd COHEN, IoMob

Philippe CRIST, International Transport Forum (ITF)

Thomas DELOISON, World Business Council for Sustainable Development (WBCSD)

Luc GARGUET-DUPORT, Renault-Nissan-Mitsubishi

Stephan HERBST, Toyota Motor Corporation

Krista HUHTALA-JENKS, MaaS Global Oy

Asuka ITO, ITF

Kazunori KOJIMA, Toyota Motor Corporation

Takayuki KUSAJIMA, Toyota Motor Corporation

David LAINE, Trafi

Martin LEFRANCQ, Bruxelles Mobilité

Irene MARTINETTI, WBCSD

Lu PATRICK, Renault-Nissan-Mitsubishi

Stefano PORRO, Pirelli and C. S.p.A

Goran SMITH, RISE Research Institutes of Sweden

Jakob SPRANGER, Toyota Motor Corporation

François-Joseph VAN AUDENHOVE, Arthur D. Little Strategy Consulting

Karen VANCLUYSEN, Polis

ITF-WBCSD Conversation of MaaS Opportunities and Challenges in North America
16 October 2020

Yuichi AOYAMA, Honda Motor Company

Alexandre BELIN, BNP Paribas

Adam COHEN, Research UC Berkeley

Aurélien COTTET, Board COTTET

Philippe CRIST, International Transport Forum (ITF)

Thomas DELOISON, World Business Council for Sustainable Development (WBCSD)

Onesimo FLORES DEWEY, Jetty

Luc GARGUET-DUPORT, Renault-Nissan-Mitsubishi

Stephan HERBS, Toyota Motor Corporation

Jens HOFFMANN, Volkswagen AG

Asuka ITO, ITF

Jari KAUPPILA, ITF

Kazunori KOJIMA, Toyota Motor Corporation

Takayuki KUSAJIMA, Toyota Motor Corporation

Sebastien MARINOT, BNP Paribas

Irene MARTINETTI, World Business Council for Sustainable Development (WBCSD)

Chris PANGILINAN, Uber

Timothy PAPANDREOU, Emerging Transport Advisors

Lu PATRICK, Renault-Nissan-Mitsubishi

Ronan PERRIER, BNP Paribas

Stefano PORRO, Pirelli

Marième ROCCHI, BNP Paribas

Daniel SASCHA-ROTH, Volkswagen AG

Jakob SPRANGER, Toyota Motor Corporation

Andy TAYLOR, Cubic Transportation Systems

David ZIPPER, Harvard Kennedy School

ITF-WBCSD Conversation of MaaS Opportunities and Challenges in Asia
11 December 2020

Yuichi AOYAMA, Honda Motor Company

Alexandre BELIN, BNP Paribas

Jason CHANG, National Taiwan University

Philippe CRIST, International Transport Forum (ITF)

Liu DAIZONG, WRI Ross Center for Sustainable Cities, China

Thomas DELOISON, World Business Council for Sustainable Development

Prateek DIWAN, WRI Ross Center for Sustainable Cities, India

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The Innovative Mobility Landscape
The Case of Mobility as a Service

This report reviews changes in today's urban mobility landscape and the potential of Mobility as a Service (MaaS) to improve travel in cities. It assesses essential governance and regulatory challenges that stakeholders must address to create a healthy ecosystem for Mobility as a Service which aligns with societal objectives and delivers clear benefits to people.

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