Viable Business or Vital Environment? Deconstructing the Sustainability Concept in Future Mobility Entrepreneurship

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Abstract

Rapid technological change in the transport sector is leading to a growing range of potential and actual 'business models' deployable for the movement of goods and people. Two key uncertainties arise from this proliferation: first, concerning which ones can be economically viable, and second, whether they can be both simultaneously economically viable and contribute to the imperatives of more sustainable mobility. The present chapter reviews and appraises the emergence of these new business models, drawing on both literature review and empirical research with entrepreneurs involved in the new mobility sector. Specifically, the potential of the UN Sustainable Development Goals (SDGs) (UN, undated) as a device to structure and frame the debate about what constitutes a valuable contribution to sustainable mobility is considered. A framework is developed which considers how mobility and transport have dependencies with the SDGs. From this analysis key sustainability concepts are derived which have either a subsistence function (maintaining the basics of human life) or an enhancement function (enabling citizens to realise their potentials whilst reducing impacts on the planet). Five different innovations involving mobility sector business entrepreneurship are then characterised using this framework to exemplify its ability to deconstruct and test claims that 'smart mobility' is also good for sustainability as well as good for business. It is concluded that the framework could contribute to a wider architecture of sustainability interrogation. It could promote discourse around a wide range of actors, posing questions and surfacing tensions and contingencies effectively, whilst providing a holistic, strategic assessment to inform more targeted, scientific evaluations of sustainability metrics.

Keywords

Sustainable Development Goals; sustainable mobility discourse; future mobility; green growth; stakeholder engagement framework; electric cars; hydrogen heavy goods vehicles; Mobility-as-a-Service; unmanned aerial vehicles; autonomous delivery robots

Introduction

The last decade has seen a striking level of entrepreneurial activity in the transport sector, covering both the passenger and freight markets. Commentators refer to the 'new', 'smart' or 'future' mobilities in indicating a significant change in the nature and extent of technologies deployable for movement of goods and people. This technological revision, if not revolution, leaves many proponents without doubt as to the economic growth potential of the sector in aggregate terms (e.g. Lerner, 2011; Graham, 2013; Van Audenhove et al., 2014; Bouton et al., 2015). However, for the individual company engaged in the daily evolution of 'future mobility' this economic prize is mostly far from secure and obvious, due to major risks about technology choices and policy stability, let alone finding demand in the marketplace. Even giants such as Tesla and Uber have struggled to achieve profitability, despite huge stock-market valuations. And as well as future mobility representing an economic opportunity, the implications for the environmental and social problems that the transport sector faces are also potentially enormous. Indeed, it is fundamental that technological change to new 'business models' must be accompanied with making a significant difference to performance against these criteria, variously at the local and global levels.

The new technologies are in the most part underpinned by growing digitalisation, which provides new options for social and economic development through new business models (Caputo et al., 2021; Pagani & Pardo, 2017). For example, connecting vehicles with each other and infrastructure leads to new business ecosystems (Epting, 2018). Here, a central proposal of the new market offers in the area of mobility is the increasing efficiency in operations and the lower climate change impact (Parkhurst & Seedhouse, 2019; Milakis et al., 2020; Nikitas et al., 2021). But this path towards more sustainable and social mobility has at best only just started. It is necessary to achieve the commitment of a very wide group of actors and stakeholders, within and beyond the transport sector, to mitigate the environmental impact of the projected growth both in freight and passenger demand. Estimates from prior to the Covid-19 pandemic were for 33% growth in freight and 16% growth in passenger traffic by 2030, and 55% and 30% by 2050 (JRC, 2019).

Original Equipment Manufacturers (OEM) are committed to the development of digital technologies and their application to mobility (Marletto, 2018), for example through automation and connectivity, variously 'Connected Autonomous Vehicles' or 'Connected Automated Vehicles' (CAV) (Whittle et al., 2019; Shergold, 2019). CAVs represent a major innovation associated with a disruptive technology, with the capacity to transform the current mobility ecosystem. The industry and its regulators are at a crossroads in deciding how to adapt the regulatory frameworks to environmental challenges whilst providing an adequate background for viable business models (Athanasopoulou et al., 2019; Rode et al., 2017; Sarasini and Linder, 2018). However, the uncertainty and the complexity of the new reality makes it necessary for the establishment of new alliances to understand new technologies and address customer demands through interdisciplinary approaches that go beyond traditional players (Pütz et al., 2019). Therefore, the boundaries of the mobility value chain are experiencing important changes, at the same time that they are being blurred because new actors appear with supposedly better solutions to address new needs from markets (Oskam et al., 2021). Hence, in this time of change, whilst evolution ought to be directed to favour more socially-inclusive and environmentally-affordable mobility fostered by new technologies, the criteria of profitability may constitute a dilemma, or worse a barrier, to such positive change.

The chapter contributes to resolving this dilemma by providing an initial analysis of some of the key technologies and business models associated with the transition. It begins in the next section by identifying in more detail the principal 'disruptive' technologies in the freight and passenger sectors. It then turns in the third section to propose a framework to consider how the United Nations' Sustainable Development Goals (SDGs) can be used to frame the policy debate amongst diverse stakeholders about these emergent technologies. The following section then provides example applications of the framework, followed in the final section by consideration of relevance of the approach for policy-makers seeking to assess innovations.

Disruptive future technologies

Freight mobility

Jaller et al. (2020) argue that the key to future freight sustainability is a combination of automation, electrification and shared resources in order to improve efficiency and effectiveness. Road transport accounts for 76.3% of freight movements in Europe (Eurostat, 2021), and it is responsible for more than 40% of Global carbon emissions from transport, with road freight alone accounting for 29.4% (IEA, 2022). A series of technological solutions will be available in the medium to long term to improve the sustainability of freight movements. The use of hydrogen and electricity as energy vectors is expected to significantly impact emissions reduction during longer distance movements (Greening et al., 2019). However, there is deep uncertainty towards future operations (e.g., readiness of technology, infrastructure requirements) and costs (e.g., production of fuels and vehicles, operational and maintenance). In particular, the future usage of hydrogen will depend on the cost and feasibility of its production technology. In fact, generation, storage, and movement of hydrogen reduce its efficiency in comparison to electricity and therefore might suggest it would be relatively uncompetitive (Greening et al., 2019). However, hydrogen remains within the policy-technology frame due the other main option, electricity, also having significant problems of commercial application.

Electrification of all modes of freight is seen as a potential option in the long term (Parkhurst, 2021). However, numerous challenges to commercial application exist related to feasibility, especially in terms of supply (e.g., availability of electricity to power the whole fleet), network design (e.g., recharging stations), technological development (especially for heavier road freight vehicles, ships, and aircraft) and overall costs. The potential demands on battery technology imply large size and weight, and so are expected to significantly reduce the vehicle's carrying capacity. Reduced capacity relative to other power trains threatens the financial viability of battery-electric business models, even if hitherto there is a lack of real-world validation of anticipated efficiencies and weight/payload availabilities (Haugen, 2021). Some concepts identify business models involving radical technology transfer, including hence high infrastructure costs and integration challenges; for example, using pantographs common in the rail sector to create 'electric highways' with overhead power supply by contact with powered wires. Heavy good vehicles (HGVs) using such a system can be lighter due to the use of a smaller battery, and consequently can carry a greater payload, and can therefore perform better in terms of value for money (Siemens, 2017). In addition, even though electric batteries would not be an option for most shipping business models, Smith et al. (2019) suggest that there are niches in which batteries can be used to power ships that travel short distances, navigating within and between ports, so able to refuel regularly.

In addition to cleaner future technologies, there might be the opportunity to use automation to increase efficiency, whilst improving the sustainability of freight movements (Paddeu and Parkhurst, 2020). These can include autonomous vessels, aircraft and HGVs on the long haul, and autonomous delivery vehicles, including autonomous ground pods and robots, and Unmanned Aerial Vehicles (e.g., drones) (Paddeu et al., 2019). In particular, PATH (2017) and MTG (2019) estimated that there would be a potential for up to €6 billion a year in fuel cost savings within Europe. However, there is deep uncertainty about the actual rate of fuel savings, as the technology is still under development (Tavasszy, 2016), and will significantly depend on the design of the road infrastructure and traffic conditions (Bakermans, 2016; Paddeu and Denby, 2021). Also, the investment cost of substituting old for new technologies is often unaffordable for small and medium enterprises, and for all businesses the improved efficiency rate is not yet sufficient to justify investment (Wiegmans et al., 2007). Nonetheless, if a viable business model emerges, the lack of access to capital or lack of economy of scale may be a cause of inequality in the future freight market, with bigger companies gaining an advantage over smaller operators. In addition, the creation of new services for digitalisation and automation will encourage new players to enter the market (Paddeu et al., 2019).

Passenger mobility

Passenger mobility business models are seen to be at a 'crossroads' due also to societal trends as well as technological evolution, or perhaps more properly due to a *coevolution* of those factors. Recent social generations (namely Generation Y "the millennials" and Generation Z "the digital natives") are identified as being less interested in owning vehicles (Focas & Christidis, 2017; Turienzo et al., 2022a) and possessing a driving licence (Tilley & Houston, 2016). At the same time, they are found to be more interested in mobility options identified as more sustainable, like walking, bus use, and cycling, among others (Whittle et al., 2019). In part this is thought to arise through greater awareness of climate change, but also due to increased collaborative and shared transport encouraged by regulators (Eckhardt et al., 2018; European Commission, 2018). Here, 'shared' can mean both synchronous or asynchronous use of transport assets by different parties (Parkhurst and Seedhouse, 2019).

This co-evolution opens an opportunity window to develop business models for more collaborative and shared transport niches. Those new technologies favour the contact and exchange among people through technological platforms that permit a higher personalisation of services (Ahmed et al., 2020; Athanasopoulou et al., 2019). One such example is subscription business models for packages identified as 'Mobility-as-a-Service' (Jittrapirom et al., 2018). Providing collaborative services requires a change in mindsets of participating businesses, which will need to take part in alliances of businesses, adopt a multi-disciplinary perspective (Pütz et al., 2019) and ultimately be willing to 'share' customers. Hence, the mobility value chain is increasingly blurring the boundaries as new participants address new market demands, particularly technological companies (Oskam et al., 2021). Some of these new business model niches are identified by their proponents as seeking to provide cleaner, lower carbon emission and more efficient mobility solutions featuring platforms (Riggs and Beiker, 2020). One such examples is the consolidation of demand and supply through dynamic simulations (Berg et al., 2020) in order to predict where demand might arise. Another is the negotiation of asset sharing, as in the case of shared-ride on-demand services (Calvert et al., 2019), facilitated by the integration of connected vehicles in the system (Turienzo et al., 2022a).

Such changes mean a new form of competition for traditional OEMs (such as Volkswagen or Toyota) but also for all mobility-related business models, including mobility support services (e.g. maintenance workshops, highway service area operators, and insurance companies). Both traditional and newcomer players report adopting demanding sustainability principles and also to be adapting their value propositions to take advantage of technological possibilities. These responses include leveraging new digital platforms and providing a higher servitisation of their activities in order to offer more personalized mobility solutions (Cabanelas et al., 2023). Examples of the sustainability commitments include a desire to use existing resources more efficiently, increasing the use and lifetime of vehicles, applying a circular economy logic (Alaerts et al., 2019). A practical demonstration of these approaches could include the better coordination of car-sharing fleets and the integration of electric or other lower environmental impact vehicles in the fleet (Globisch et al., 2019; Whittle et al., 2019).

Joining these initiatives is the principle that, if information flows between travellers and companies in a more connected way, the collective value proposition will be enhanced, and be directed towards increasing the sustainability of the whole passenger transport system. At the same time, better information can underpin greater individuality of service offer, and this could potentially increase the inclusivity of the system of mobility.

Whilst the rhetoric is clear and strong, whether these freight and passenger promises will be achieved must be subject to continual validation and analysis. The next section develops a framework for aligning stakeholder perspectives towards what constitutes a significant and deliverable shift towards sustainable mobility.

The Sustainable Development Goals as a Framework for Sustainable Mobility Policy Development

The United Nations (UN)'s 17 Sustainable Development Goals (SDGs) (UN, undated) have been under development since the Rio de Janeiro Earth Summit of 1992 and are the centrepiece of the 2030 Agenda for Sustainable Development, adopted by UN Member States in 2015. The SDGs emphasise that environmental recovery and protection cannot, effectively or morally, proceed without integrated and concerted action to address social objectives including poverty, inequality and access to healthcare and education. Achieving these objectives will also require economic growth of a sympathetic nature.

The SDGs as a tool for sharing perspectives on sustainability

The SDGs represent a significant achievement in that they identify universal goals accepted by 193 national governments. However, they have been subject to a number of criticisms, summarised by ICSU/ISSC (2015). The SDGs can be seen as establishing endpoints without identifying process means of reaching them. Indeed, as an evaluation tool, the SDGs have been seen to be limited by the lack of quantifiable targets and timelines. The SDGs are also argued to be oriented towards the perspectives of national governments, rather than the wide range of stakeholders that need to be engaged to deliver them, notably those in the private sector. Furthermore, the 17 SDGs and their 169 targets had been identified as tending to promote 'silo' policy thinking, whereas there are important interactions between them and a recognition, including by the UN, that they need to be overlaid by principles or themes which are even more fundamental, such as the 'six elements': people, planet, prosperity, justice, partnership and dignity (UN, 2014).

Despite these criticisms, the SDGs nonetheless have a salience far beyond national governments and the public sector. Business consultants such as Ernst and Young extol the virtues of companies building them into strategic plans (Ernst & Young Global Ltd, 2017), and a survey has identified that more than four-fifths of companies use the SDGs as a framework against which to align their sustainability reports, even if they are limited as a tool for assessing progress (GRI, 2022). And whilst needing further development, the SDGs are also already a recognised 'brand' being applied at wide scale in assessing company performance. The World Economic Forum (2021) reports on an assessment of 8,550 companies in the MSCI All Country World Index (finding that only a fraction were "strongly aligned" and around a fifth "aligned" with the goals).

Given their high recognition beyond the scientific community, and use by politicians, educators, and business, the present chapter takes the view that the SDGs are, *de facto*, the framework within which different stakeholders are most likely to develop shared perspectives on development, including technological transitions. To this end the chapter seeks to demonstrate how the SDGs can be applied to a specific case in order to enable the structuring of the complex reality of policy decisions (Schön and Rein, 1994). In this context, scientific predictive scenarios and ex-post evaluations are critical sources of information and evidence to test and validate the policy framings around the SDGs, but that framing is itself a distinct process of building (or not) a consensus around change. Indeed, as Genus and Stirling (2018) emphasise, exploring 'dissensus' is fundamental to question strongly-asserted powerful interests and avoiding path-dependent or incumbent patterns of decision-making.

The approach also seeks to address the critiques that the SDGs must be applied in a relevant way, and consider interdependencies. To this end it explores an approach to grouping the SDGs applied to the case of transport and mobility policy. In doing so it emphasises key themes in the delivery of change.

SDG dependencies on transport and mobility

There is, perhaps rightly, no SDG for mobility or accessibility. The demand for transport services is mostly a 'derived demand', in that most of its socio-economic welfare benefits derive not from the movement itself, but in facilitating access to goods, services, restorative environments, and social opportunities. However, for this very reason, several of the SDGs are contingent upon effective levels of physical accessibility. Depending on the socio-technical and built environment context, achieving accessibility often means using mobility services secured through one's own ownership of assets (e.g. car, bicycle) or renting assets owned by other (e.g. car hire) or paying to receive a transport service (e.g. bus, train, or aeroplane journey). Table 1 summarises the principal dependencies between the SDGs and mobility in terms of the key motivations for movement (or, increasingly, and characterised strongly by practices during the COVID-19 pandemic, its substitution through virtual mobility).

Table 1: Principal dependencies between the SDGs and mobility

SDG Number and Scope	**Dependencies on mobility and transport services**
1 End poverty in all its forms everywhere	Affordable access to a level of mobility services that facilitates at least the basic needs of life
2 End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Efficient transport from the places of food production to markets via the transport system Physical or virtual access to marketplaces for food purchase, or via delivery services
3 Ensure healthy lives and promote well-being for all at all ages	Access to health services by physical means, although telemedicine of growing relevance Access to spaces which engender wellbeing (nature, historic environments, places of value to the individual), mainly physically, although virtual access of relevance in some circumstances
4 Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	Physical and virtual access to the places of education and training – both modalities are now important due to the digitisation of knowledge and learning
5 Achieve gender equality and empower all women and girls	A transport and telecommunications system which offers services to all citizens without the threat or reality of physical or psychological harm during mobility, and which overcomes historic gender injustices in access to opportunity

6 Ensure availability and sustainable management of water and sanitation for all	Although for many citizens globally, high quality water is found within the home or nearby, for many, travel for and transport of water it is still part of the daily grind of chores. Enhanced water infrastructure is essential to minimise this need for travel.
7 Ensure access to affordable, reliable, sustainable and modern energy for all	The transport of fossil fuels perpetuates global warming, adds to energy costs, and results in injury and deaths through fuel tanker collisions. Enhanced energy infrastructure is essential to bring clean, renewable energy to the home to minimise this need for transport.
8 Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	Physical mobility – daily or seasonal - to access a labour market with a range of opportunities is one of the traditional objectives of transport policy and planning. Increasingly, virtual access for remote working is also important to deliver access to employment
9 Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	Transport and communications services which use infrastructures in an efficient way, without imposing undue pressures on operating costs, capacity and longevity through extreme congestion or vehicle weight
10 Reduce inequality within and among countries	A level of international mobility of people and goods which enables resources to flow to places suffering inequality and enables people to migrate to places of opportunity without unsustainable levels of environmental impact
11 Make cities and human settlements inclusive, safe, resilient and sustainable	Transport systems which serve their cities rather than dominating them to the exclusion of their primary purposes of being living spaces
12 Ensure sustainable consumption and production patterns	Linking the places of production and consumption with an intensity and efficiency that minimises energy demand and preserves local specialism
13 Take urgent action to combat climate change and its impacts	A transport system which will progressively and rapidly reach 'net zero'
14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development	Marine transport systems with drastically reduced environmental pollution (combustion, waste and noise emissions) and physical disturbance
15 Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	Minimising the demand for additional land-take for transport infrastructure provision by using existing networks as efficiently as possible
16 Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	Services regulated to meet needs of all citizens, so no one, literally and figuratively, is left behind
17 Strengthen the means of implementation	Ensuring that professionals, volunteers, and

and revitalize the global partnership for sustainable development	citizens engaged in sustainable mobility have the capacity and capability necessary to deliver against SDGs 1-16 as they relate to travel and transport locally, nationally and internationally

Table 1 confirms that mobility policies and practices have implications for all 17 SDGs. In some cases (e.g. 9, 12, 13) transport activity has a direct impact on their deliverability. In many, transport plays a key facilitating role (e.g. 2, 3, 4, 8). For water (6) and energy (7), the preferred outcome is promoted by the extent people and commodities no longer have to travel, except by pipeline or wire. For some, transport and mobility present one important facet of the problem or development need (5, 10, 11, 15, 16). Lastly, 17 represents the sector's ability to delivery change.

Taken at scale and in its full intent, the project of 'new mobility' identified in the introduction might have significant impacts on the broad dependencies of Table 1. Individual new mobility services will affect those relationships in specific ways, potentially with positive influence on some SDGs, and negative on others. Hence, the authors draw upon existing qualitative datasets developed through earlier projects which explored the emergence of new mobility services to examine those possible implications from the perspective of their architects and promotors. The data arise from individual expert interviews conducted in Spain, Portugal, UK with professionals involved in technology development in the transport sector, mainly focusing on passenger transport (MoBAE Project, CAPRI Project) and focus groups and workshops with professionals involved in the process of freight decarbonisation in the UK (CoDeZero and CRAFTeD projects). In each case the data and results have been re-analysed through the lens of the SDGs.

For these analyses, the SDG dependencies are categorised in two groups (with SDG17 related to delivery outside those groups). The first group focuses on the connectivity that movement provides and how this directly underpins the SDGs which underpin subsistence in human life. The second has a more indirect, process-oriented relationship, which considers how the quality of transport and travel services influence the quality of life (Table 2).

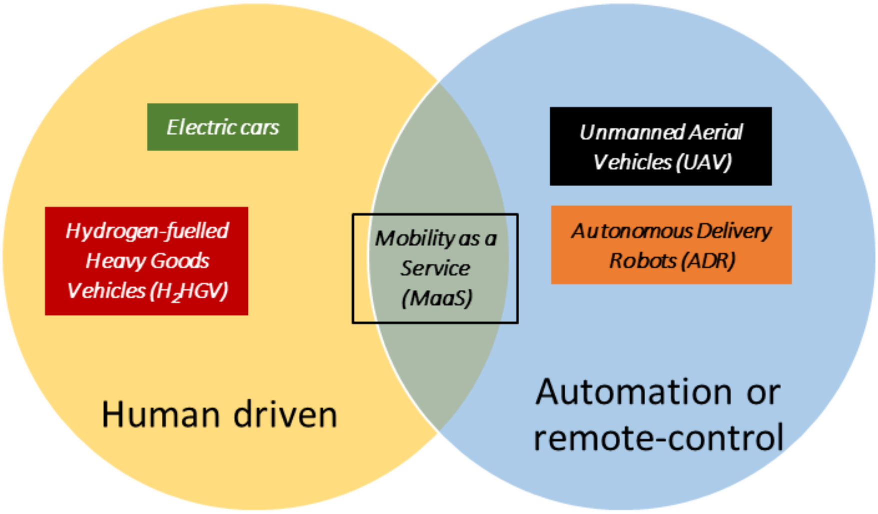
Table 2: SDG-Mobility Dependencies in terms of Subsistence and Enhancement of Quality of Life

Group	**Key concepts from dependencies**
Outcome-related or subsistence SDGs 2/6/7-hunger, thirst, comfort 3-health and wellbeing, 4-education, 8-employment	Movement to Connect with Goods and Services • Food, Water, Energy • Healthcare, Spaces for Wellbeing • Education • Employment
Process-related or enhancement SDGs 1-poverty 5/10-gender and other equality 9-resilience 11-urbanisation 12/14-sustainability/conservation 13-climate neutrality 15-biodiversity 16-accountability	Quality of Services for Transport and Travel • Affordability, • Inclusion: Availability to all, Security • Within technical system and ecosystem capacity • Human-scale infrastructure • Energy efficient, low noxious emissions • Low or zero GHG • Space efficient • Regulation in interests of public
Delivery-related SDG 17-implementation	Capacity and Capability • Sufficient agents of change

Applying the SDG-Mobility Analysis Framework

Taking the framework developed in the previous section, we apply it to five cases of future freight transport and passenger mobility technologies and their related business models. The cases variously consider freight and passenger mobility, air and surface transport systems, small scale vehicles up to the largest road vehicles, and two cases which emphasise technology substitution, whereas three involve much more complex socio-technical and behavioural change. Two of the latter would use either automation or remote-control operation, for the third it could feature in the business model (Figure 1).

Figure1: Cases of mobility innovation with and without automation



Unmanned Aerial Vehicles (UAV)

Whilst passenger UAVs (pilotless aero taxis) are under development, freight drones are already offering some services. Drones can be used in combination with local transhipment hubs (such as consolidation centres) for 'last mile' deliveries. Possible applications include rural areas with low road transport accessibility, and congested urban areas.

Drones can potentially support subsistence SDGs in the following ways, with providing alternatives to poor or absent infrastructure being a theme:

- Food – drones can be used to support smart agriculture (Kim et al., 2019), to increase production from smaller farms (Zhong et al., 2018) and as robot pollinators (Chechetka et al., 2017). A freight transport niche might be to transport high-value, low-weight produce to local markets in a timely fashion.
- Health and wellbeing – an established drone niche is for urgent deliveries of medical supplies to low-accessibility places, where the road infrastructure or congestion would not allow other efficient and timely road delivery options; or in humanitarian supply chains, such as emergencies and disasters (Singh and Frazier, 2018).
- Employment – they can be potentially used to replace vans in very congested areas (Paddeu et al., 2019). This might have a significant impact on employability: van drivers, for example, would be replaced, but new job profiles (drone handlers, drone operators-overseers), would be created. However, the literature does not provide any information on the specific impacts

(Aurambout et al., 2019), but in some locations drone services might be additional, so create employment, in others they may be an efficient alternative, requiring lower labour inputs. Drones also can be used for handling tasks in the local hub, as they have been shown to be significantly more efficient than human operators (Paddeu et al., 2019). For example, two drones can carry out the work of 100 humans (i.e., in terms of handling, picking and order preparation) over the same time period with an accuracy close to 100%, with warehousing and logistics cost savings (Jackson, 2017). These advantages might have a significant impact on the currently growing employment concerns within the logistics sector (Paddeu et al., 2019). The outcome would ultimately depend on the local labour market, but there is clear potential for automation in general to reduce employment opportunities (Lawrence et al., 2017).

Considering SDGs for enhancement:

- Affordability – investment costs, at least initially, are expected to be high, and this could tend to create inequalities in terms of market accessibility, as bigger players will be able to invest, and smaller players might be excluded (Paddeu et al., 2019). If the services are expensive, they may tend to be applied in niches which benefit the relatively wealthy, rather than the poor.
- Inclusion – in principle the services would be open to all, provided digital exclusion is avoided, and particular locations are not excluded based on economic viability or incidence of crime.
- Within system capacity – as drones are an aerial transport system, infrastructure demands are relatively low and specific, requiring vertical take-off and landing areas, or short runways. Along with all electric vehicles, there are questions and uncertainties around the environmental impact of sourcing raw materials for batteries and their subsequent recycling.
- Human-scale infrastructure – hitherto most drones for civilian purposes have been small; indeed, fitting into the existing built environment is one advantage. This may not remain the case for all future applications, however.
- Energy and noxious emissions – aviation is fundamentally energy intensive, but can represent the most efficient solution e.g. if the alternative is an over-sized road vehicle taking an indirect route over hilly terrain. Noise emissions are a potential problem in urban areas and may limit operating practices.
- Low or zero GHG – assuming electric technology, there is the potential for zero-GHG emissions, depending on how electricity is produced (Portapas, 2021).
- Regulation in interests of public – probably the most significant barrier to the implementation of this technology is public acceptance. The public would need to be convinced that the services do not represent a threat to privacy, security, or safety (Aurambout et al., 2019; Paddeu et al., 2019). There is a need for new regulations (Paddeu and Parkhurst, 2020).

Regarding capability and capacity (C&C), training would be needed not only for commercial operators but also for citizens in order for them to be able to interact with the technology (Paddeu et al., 2019).

Autonomous Delivery Robots (ADR)

Small wheeled robots can be used to undertake B2C last-mile deliveries (and in this context the typical range would be within a mile or so).

In respect of subsistence SDGs, ADRs have some similarities with the UAV equivalents, although they are constrained by using surface infrastructure and hence lower speeds due to interacting with other road users and obstacles in the built environment:

- Food – ADRs can be used for food last-mile deliveries. Whilst in many cases this might be an added-value service to save the consumer a journey, some citizens may be unable to travel
- Health and wellbeing – ADRs can deliver medical supplies, although in the case of time-critical deliveries may not offer the fastest option. During the COVID-19 pandemic, Abrar et al. (2020) suggested that ADRs could be a secure and contactless delivery option to counter the spread of the virus.
- Employment – similar to drones, ADRs could potentially replace human-driven vans in very congested areas, as they can circulate on the pavement sharing the space with pedestrians (Paddeu and Parkhurst, 2020). This might have a significant impact on employability (e.g., van drivers would be replaced). On the other hand, this could actually represent a partial solution to the truck/van driver shortage that is significantly impacting the logistics sector.

Considering SDGs for enhancement:

- Affordability – currently, the high initial investment costs of ADRs limit their widespread adoption. In fact, many companies that could potentially adopted ADRs can be expected to wait until the technology is further developed and tested (e.g., available and implemented on a large scale at a lower price), in order to avoid potential risks of misdirected investment (Zhang, 2019). Given the costs will need to be met by the consumer, until they reduce, the services are unlikely to be viable for most citizens.
- Inclusion – as with drones, there is a risk that some groups might be excluded, due to difficulties interacting with the digital and physical technologies (Paddeu et al., 2019), although ADRs could offer 24-hour delivery services, so meeting individual needs.
- Within system capacity – ADRs are designed to work with the existing infrastructure, although some adaptation may be necessary for their widespread adoption. All ADRs are likely to be electrically powered, adding to the transport system demand for batteries.
- Human-scale infrastructure – ADRs tend to be relatively small. However, they are intended for pavement use and therefore may constrain the use of pavements by humans wishing to exercise the most fundamental mobility right: walking.
- Energy and noxious emissions – as in the case of drones, energy efficiency will depend upon appropriate application, but there is potential to significantly reduce the number of failed deliveries (e.g. through offering evening delivery). Missed deliveries currently account for 5% of total e-commerce deliveries (Paddeu et al., 2019). Noxious emissions will be minimal due to electric power and low weight, so low tyre wear. Noise emissions will also be very low; a key advantage over drones.
- Low or zero GHG – being electric, ADR have the potential to reduce GHG emissions. However, it would be important to explore the added value they can provide in terms of environmental impact, when compared with human-driven electric vehicles.
- Regulation in interests of public – at the moment there are no regulations to allow ADRs to circulate on public roads. Previous studies identify resistance from pedestrians to sharing pavement space (Paddeu and Parkhurst, 2020), and it would be important to respect these views when seeking to update highway use codes to accommodate ADRs.

C&C is likely to be less safety-critical than for an aerial system, but training for commercial operators and citizens will still be necessary (Paddeu et al., 2019).

Hydrogen-fuelled Heavy Goods Vehicles (H_2HGV)

The third case considering freight transport radically increases both the scale of mass being moved and the distance of typical operation (to medium-to-long distances). It also represents an example of technology substitution with minimal behaviour or context change required beyond the important exception of new fuel supply infrastructure provision.

For this reason, impacts on subsistence SDGs are likely to be relatively minor. Provision of goods to support food, health, education etc. would be not directly affected by a switch to hydrogen, although access would be maintained whilst furthering other SDGs.

- Employment – the growth in the hydrogen industry has the potential to create a high number of new employment opportunities in a wide variety of industries (Bezdek, 2019). A recent study in the Netherlands estimates that the effect could be a net increase: green hydrogen could preserve and create up to 100,000 jobs a year by 2050, with one-third being new jobs created by the introduction of hydrogen (EM, 2021).

Considering SDGs for enhancement:

- Affordability - companies wishing to buy hydrogen trucks would face high initial investment costs. Moreover, cost and feasibility remain very uncertain. The main rival, electrification, is not a viable option in the short to medium term, but in the long-term electric vehicles are expected to perform better both in terms of operations and costs (Greening et al., 2019). This increases the risk of investment for those companies who want to invest in hydrogen in the short term. Higher costs in the short-run might be passed on to consumers, having a negative impact on poverty, although in the long-run the outcome might be positive, given the rising costs of fossil fuel extraction and production.
- Inclusion – alongside affordability and perceived risk, the lack of technical knowledge and infrastructures necessary for H_2 vehicles would, without intervention, be a barrier to participation in the transition, particularly affecting smaller operators.
- Within system capacity – the H_2 economy has the potential to underpin a circular economy. As in the case with electric powertrains, there are environmental impacts associated with the production of fuel cells, such as minerals used as catalysts, to be considered.
- Human-scale infrastructure – there is the potential for H_2 to be produced in a larger number of local facilities rather than at major refineries, which, if economically viable, would be at a more human scale.
- Energy and noxious emissions – practices for H_2 production and compression for use in road vehicle fuel cells mean it is less energy efficient than the best electric technologies, but with advantages over internal combustion engines. Due to the only emissions from fuel cells being water, there are positive implications in terms of air quality and indirectly on public health due to the elimination of pollutants including Oxides of Nitrogen and particulates from exhausts. However, current production options can produce noxious by-products (Lewis, 2021).
- Low or zero GHG – depending on the way hydrogen is produced, HGV-H_2s have the potential to be zero GHG emission (Greening et al., 2019).

C&C have a particular role within the freight sector to enhance knowledge and skills necessary for the transition to H_2.

Mobility as a Service (MaaS)

The *servitization* of mobility involves the emergence of digital platforms to connect companies and travellers, and large amounts of data provided by connected vehicles. It therefore combines technological change with behavioural change, opening the prospect of significant system wide changes which may facilitate, or obstruct, the achievement of the SDGs. However, the concept of MaaS covers a wide range of practical applications. Indeed, Mladenović and Haavisto (2021) identify the 'interpretive flexibility' of the concept as leading to lack of clarity about the objectives and likely outcomes of the approach, leading to a risk of unsubstantiated enthusiasm, even amongst public sector actors.

According to the nature of the implementation, the impact on SDGs can be expected to vary in important respects, and it would be important to interrogate the specific business model, not solely a generic concept. However, if new MaaS offers do facilitate travel behaviour change, particularly amongst those who suffer from accessibility constraints, the SDGs for Subsistence in general could potentially be strongly impacted, particularly in respect of:

- Health and wellbeing – access to services can be particularly problematic for disabled and older people where fixed transport schedules do not align with appointments. Access to on-demand transport with a wider range of options and alternatives (Shergold, 2019) can make personalised but collective transport affordable.
- Education – students might have more mobility opportunities, widening choice of school or higher education location and reducing constraints brought by limited accessibility (Turienzo et al., 2022a).
- Employment – labour market flexibility could be strongly enhanced (Calvert et al., 2022). However, some change in employment roles in the transport sector can be expected due to the partial replacement of traditional public transport with MaaS. Further investigation is needed to better understand the impact of the digital economy, particularly on the need for low-skilled roles.

Considering SDGs for enhancement:

- Affordability – multimodal integration combined with a transfer from private to collective modes can reduce transport costs (Liu et al., 2017), offering more options to people with limited resources through a holistic design of pricing (Pangbourne et al., 2018). However, the extent to which access differences among social classes will persist likely depends on wider success in implementing the SDGs.
- Inclusion – if applied correctly, greater digitalization will improve real-time information to identify and solve problems, to detect inappropriate behaviours and to increase the objectivity of public information and extent of services, connecting the city better with the suburbs and rural areas. However, there remains a risk that personal data could be used inappropriately, to exclude particular citizens or social groups.
- Within system capacity – the high availability of behavioural data combined with the analytical power of companies and governments could facilitate the scenario simulation to predict demand and the establishment of contingency processes to deal with unexpected phenomena. Such possibilities will be of particular benefit to road infrastructure managers (Turienzo et al., 2022a).
- Human-scale – will be improved by the higher efficiency and individuality of the transport system, using a greater share of micromobility (bikes, e-scooters, walking) rather than large vehicles.

- Energy and noxious emissions – the effective use of existing resources may enhance energy efficiency, but further evidence about the nature of behaviour change is necessary to evaluate whether, as a result of the service packages offered to consumers, the relatively efficient or inefficient modes benefit most. Emissions will depend on the powertrains of the selected options, but MaaS could promote the electrification of mobility, avoiding local exhaust emissions.
- Low or zero GHG – similarly, the integration of electric or other green technologies in the MaaS fleet would promote zero carbon emissions, but the fleet mix in practice needs to be better understood.
- Space efficiency – if transport assets such as vehicles and roads can be used more efficiently, this would reduce the pressure on natural resources (Alaerts et al., 2019).
- Regulation – a high level of coordination of the whole system will be necessary to facilitate the better use of existing resources and social inclusion. The high importance of personal data also raises protection and security matters. An important role for the state as regulator will be necessary.

Significant C&C implications relate to the digitalisation of transport, requiring new skills in the sector, whilst the more traditional skills of integration will remain important.

Electric cars (EC)

Here we consider the purely battery-powered plug-in EC, and no forms of hybrid, which, having dual powertrains, are more complex in respect of the SDGs. With several similarities to the case of HGV-H_2, the EC represents a 'business-largely-as-usual' approach to seeking greater sustainability for the private car. For this reason, the major change in respect of the subsistence SDG dependencies is with:

- Employment – even more so than in the case of HGV-H_2, there are major implications in terms of changing roles for vehicle assemblers and maintainers, and for the support services around charging rather than liquid fuelling.

Considering SDGs for enhancement:

- Affordability – in the short-run, ECs are like-for-like more expensive to produce than their internal combustion engine equivalents. However, those costs are expected to fall along with enhancements in battery technology, and there is a clear advantage in terms of operating costs with respect to fossil fuels for cars, even if all energy costs have been rising globally. In the long-run, there is the potential for electric technology to lower the costs of transport products and services, offering some potential to reduce poverty (Börjesson et al., 2021).
- Inclusion – fundamentally, an EC is a car, and cars are associated with significant inequalities in mobility. New forms of service associated with the EC would be necessary to increase inclusion. Moreover, there is reason to believe that ECs could be a source of greater inequality, as some citizens who can own an ICE car would not be able to own an EC, due to charging constraints as well as capital cost (Parkhurst & Clayton, 2022).
- Within system capacity – reduced reliance on globally traded fossil fuels is expected to enhance the independence and resilience of some national economies, although dependence on specific commodities for battery production will likely create new dependencies. The new independence may be translated into public policies that foster the transition of their economies in a more balanced, competitive and socially-equitable way. The EC support industry has the potential to offer a source of 'green jobs' and new business

opportunities in the development of infrastructure and vehicles. The continuous technological evolution in this field is opening up promising areas of development. These could include start-ups for the development of new battery technologies and better battery management, including the circular economy around batteries (Turienzo et al., 2022b). Without an effective circular economy for batteries, there will be massive challenges for companies, policymakers and society in general as to how to source new raw materials and manage waste.

- Human scale – as the EC is essentially another kind of car, the human scale can only be respected by ensuring that alongside the transition to ECs, the personal-scale modes (micromobility) are given the greatest priority, otherwise our cities will continue to be congested with vehicles and the roads unsafe.
- Energy and noxious emissions – in many cities, ECs are subject to favourable regulatory and fiscal treatment, reflecting the benefits of zero tailpipe emissions and lower noise, expected to enhance the wellbeing and health of citizens (DBEIS, 2017). However, ECs are not generally being specified as energy-efficient vehicles, as they are designed to match or exceed the performance of the ICEs they replace, most of which are already over-specified for their 'duty cycle'. The energy-efficiency contribution of the transition to ECs would be enhanced by re-thinking the role of the car in society (Parkhurst & Clayton, 2022).
- Low or zero GHG – transport is responsible for almost 15% of greenhouse emissions worldwide, and road vehicles are the main source. Amongst those, cars are the largest contributor (Black et al., 2016; Greene & Parkhurst, 2017). As noted under efficiency, ECs currently represent a partly-missed opportunity. Moreover, to offer a benefit for all, the electrical energy must in the future arise from net-zero GHG sources; a major challenge for the electrical supply industry. Reduced demand for personal mobility by car may be the only means to overcome the challenge of sourcing sufficient green energy.
- Space efficiency – there are two areas of concerns with ECs. First, by signalling greener and cheaper motoring to the consumer, demand for car travel may rise, and without new policies to manage demand, the need for additional roads, and hence loss of habitats, will grow. Second, whilst biodiversity may be favoured by reduced air pollution and GHG emissions, the challenges of raw material extraction for manufacturing batteries predominantly affects the industrialising states. However, reduced demand for new oil fields may reduce the risks faced by the few wild landscapes, such as found in the Arctic or Antarctica.
- Regulation – the rise of the EC brings new challenges for regulators ranging from the road safety implications of their quietness compared to traditional cars, through to who is responsible for organising an efficient network of recharging facilities. The state will also have an important role in managing the transition within an automotive sector that is traditionally a major provider of employment at a range of skill levels. The higher connectivity of future vehicles will also bring responsibilities to avoid cybercrime, whilst taking the opportunities for better highway and traffic management. Strong regulation of the circular economy around batteries will be necessary.

In respect of C&C, citizen-users of ECs will need only modest upskilling to change fuelling and driving practices, but major new skill sets are necessary in the sector to deliver charging infrastructure and to maintain the electric powertrain.

Relevance of the Framework for (De)Constructing Sustainable Mobility

The chapter could only examine five of the many business models and new technologies currently emerging in the sector. Nonetheless, the SDG-derived framework emerges as a relevant tool to encourage holistic thinking and debate around the impacts of new technology business models in the mobility sector. The approach reduces the 17 goals to a smaller number of mobility-oriented dependencies. Its particular value is a practical one of building upon the leading set of internationally-endorsed sustainability criteria which are already in use by businesses and governments globally, and having high salience with citizens.

The specific assessments provided here are provisional, and no doubt partial. However, a notable concluding observation from the indicative application presented here is that the exercise underlines how wide-reaching change in transport supply, as a derived demand, can be. Most of the cases would have positive and/or negative consequences for most of the 17 SDGs. However, it was notable that the two technology substitution cases (HGV-H_2 and EC), as well as avoiding the need for behaviour change – indeed this is the intention of substitution – also offered little in respect of altering the dependencies connected to subsistence. In other words, they make little difference for policy-makers seeking to enhance access to food, water, energy, healthcare, spaces for wellbeing, or education. The one exception here was 'employment' and even here the change is through altering the nature, and perhaps increasing the quantity, of employment in the sector, so the relationship is a secondary one, rather than through a spatial change in labour markets due to new transport services.

The three cases offering more 'disruptive' change, deploying more radical technologies and requiring more behavioural change would tend to affect a wider range of dependencies. Here, the changes to the more fundamental SDGs of subsistence could be important: UAVs, for example, might be a way of transporting produce from remote African villages to the nearest market when the roads are impassable in the wet season, whilst MaaS could revolutionise access to healthcare in rural areas.

In all cases the analyses identify a few clear and strong potential sustainability contributions, such as zero local noxious emissions, but in most cases the assessments are strongly conditional, subject to better evidence, or down to the net outcome of effects in different directions. For example, reduced GHG emissions are generally subject to the means of generating the energy consumed, with generation occurring in another part of the economic system. Energy efficiency may be enhanced, but it may not be optimised to the extent that would be achieved if external costs are given a higher weighting. Reduced noxious emissions in the local environment may be accompanied by more visual and physical intrusion, and poorer road safety, if reductions in emissions are a factor in perpetuating the dominance of car traffic in cities.

Indeed, these latter uncertainties are examples of the wider principle that what constitutes responsible innovation at any one time is informed by partial and emergent scientific understanding of new technologies, and is always socially and political constituted (Stilgoe et al., 2013). The SDG-referenced framework offers potential particularly to engage stakeholders in addressing, questioning and critiquing that construction, at a strategic level. As such it can only contribute to a wider architecture for effective governing innovation, in particularly one that embraces scientific study including quantitative evaluations of expected or actual outcomes against targets.

Nonetheless, in order to promote debate, interrogate claims and bring tensions and inconsistencies to the surface, the framework provides business and policy actors in the mobility domain with an accessible operationalisation of the SDGs. In doing so, it facilitates consideration beyond the immediate behavioural or technical implications to consider more fundamentally what major change in the transport sector could mean in terms of maintaining the basics of human life, and enabling the human race to actualise a higher level of collective wellbeing.

In practice, the approach would likely function best as an initial scoping analysis tool for policymakers or entrepreneurs wishing to clarify the wider sustainability implications of new business models and technologies, before identifying the most important dependencies in each case for more fundamental analysis. However, they provide a framework to test in broad terms whether sustainable mobility claims are a deep driver or superficial gloss for mobility innovations.

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Bio notes

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