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Technology, transport, and the sharing economy: towards a working taxonomy for shared mobility

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ABSTRACT

In recent years, there has been a growing interest in studying the interactions between the fields of digital technology and transport and multiple terms to describe these interactions have been proposed. These include terms such as "smart mobility", "new mobility", "3-revolutions" and "Mobility-as-a-Service", amongst others. While these terms encompass a wide range of technology-transportation interactions, all of them include shared mobility as one of its elements, yet there is still no broadly accepted definition in the academic literature of what the term "shared mobility" means or what type of technology-transport interactions it encompasses. The aim of this paper is to propose a taxonomy for shared mobility based on a critical engagement with the main bodies of literature across disciplinary areas that underpin this concept: (1) the interactions between digital technology and transport, and (2) the broader concept of the sharing economy. Though these two elements are sometimes mentioned together in the literature as relevant to shared mobility, to the authors' knowledge they have not yet been combined in a published study to explicitly propose a definition or taxonomy. Having a clearly defined and broadly accepted terminology for shared mobility is important, as this is a term that is used not only in the academic literature, but also by policymakers and in policy documents, and the lack of a definition leads to a lack of clarity and shared understanding of what shared mobility involves. The literature reviewed carried out for this paper suggests that different authors use the term shared mobility in diverse ways to refer to a diverse set of solutions. The proposed taxonomy can therefore be used by public and private policymakers and academics alike to speak a common language when referring to, planning for, and evaluating shared mobility solutions.

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Shared mobility; definition; taxonomy; smart mobility; sharing economy

Introduction

The topic of "shared mobility" has sparked interest in the academic literature in recent years despite there not being a clear consensus on what the term encompasses (Le Vine & Polak, 2015). Shared mobility has been proposed as solution to current

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sustainability challenges by, for example, reducing greenhouse gas emissions (Shaheen & Cohen, 2019), reducing car ownership (Shaheen & Chan, 2016), or improving transport access for low-income populations (Kodransky & Lewenstein, 2014). Without a broadly accepted definition however, assessing the real benefits or drawbacks of shared mobility as a sustainability strategy becomes challenging, as different authors, policy makers, and evaluators may have a different understanding of what shared mobility means, or even which mobility solutions belong to this term. A lack of unified understanding of shared mobility therefore creates a state of "conceptual confusion" (Lembcke, Herrenkind, Willnat, Bührke, & Nastjuk, 2020) that leads to different stakeholders using a single term to refer to different ideas. The oldest reference to the term found dates to 1995 from Engels et al. (1995) in a paper in which the authors propose a real-time hitchhiking solution by using the (then) newly developed mobile phone network (GSM). To put this into context, this was the same year in which SMS services first became commercially available. Whilst this might be one of the first uses of the term, the concept of sharing vehicles and rides between multiple users aided by technology predates 1995. For example, writing in the 1970s, Alexander (1977) described a primitive form of what today would be called "ride-sharing" or "demand responsive transport" using the available technology at the time:

> (…) a system of small taxi-like buses carrying up to six people each, radio-controlled, on call by telephone, able to provide point-to-point service according to the passengers' needs, and supplemented by a computer system which guarantees minimum detours, and minimum waiting times. Make bus stops for the mini-buses every 600 feet in each direction, and equip these bus stops with a phone for dialling a bus. (Alexander, 1977, p. 112)

Despite these early visionaries, the contemporary meaning of the term started to develop within the broader concepts of the "smart city" in the 1990s (Albino, Berardi, & Dangelico, 2015) and the "sharing economy" in the early 2010s (Schor & Attwood-Charles, 2017). As Figure 1 below shows, the use of the term "shared mobility" started to grow in academic publications by mid-2010 – only after these other concepts had already been proposed.

This paper explores the origins and uses of the concept of shared mobility in two of the main fields of literature that underpin it: (1) transport and Information and Communications Technology (ICT), and (2) the sharing economy. Based on these two bodies of literature, the paper engages in a critical review of previous definitions to subsequently propose a working taxonomy of shared mobility that can be used both in academia and by public policymakers, allowing for a common understanding of this term.

Review of the literature

The identification of the literature reviewed for this paper was carried out using searches on Web of Science, Scopus and Google Scholar between September 2018 and April 2020, with a final update in June 2021. The specific focus of the search was on those papers that discussed previous definitions of the terms. The first area of literature reviewed was the one pertaining to the interactions between ICT and transport. This area of literature is expansive since the combination of both sectors into a distinct area of study started to happen towards the decade of the 1930s (Masaki, 1998). Terms such as Intelligent Transport Systems (ITS) have been used for decades and while still ambiguous, are broadly

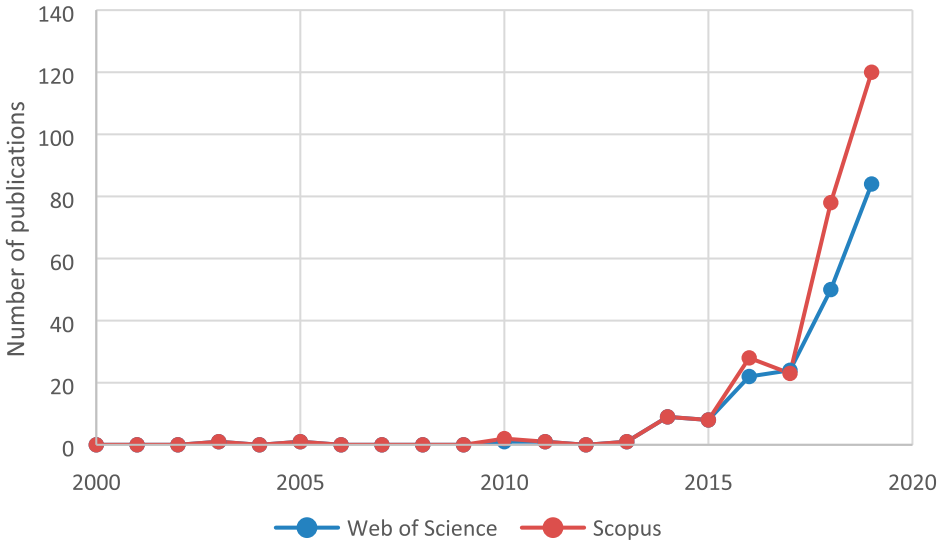

Figure 1. Number of peer reviewed publications from 2000 to 2019 that mention the term "Shared Mobility" in their title, abstract or keywords, using data from Web of Science and Scopus. Search carried out on April 2020.

used by practitioners and academics alike, and have been thoroughly reviewed by other authors (e.g. Auer, Feese, & Lockwood, 2016). There are however other terms such as "smart mobility" that have more recently started to appear in the literature and that have not been as thoroughly studied, and therefore were the focus of the review. While there have been a few attempts to define these terms, there is still no consensus on their boundaries. The current paper therefore focuses on identifying shared characteristics amongst these different attempts to identify which of these characteristics can form part of a definition of shared mobility. The search for papers included terms such as: "new mobility", "intelligent mobility", "shared mobility", "intelligent transport/ation systems", "mobility as a service", "MaaS", and "innovative mobility", all complemented by the term "definition" and its derivatives (e.g. "defining") as well as "taxonomy". These searches produced a limited number of articles that, after an initial screening to evaluate their relevance, were narrowed down to 25.

The other area of literature relevant to the topic of the current article is the one that discusses the concept of the sharing economy. The term started to appear in the literature around 2015 and therefore most of the articles reviewed for this paper on this topic date from the decade of the 2010s, with a few exceptions of older articles referenced by those in the initial search. As with the literature on ICT + Transport, the review of literature for the sharing economy was centred around those papers that attempted to define the concept and therefore could be used to identify its most basic characteristics. Here the terms used for the search were: "sharing economy", "shared economy", "collaborative consumption", complemented by "definition" and "taxonomy" which resulted in 27 selected papers.

In addition to these areas of study, there is already a growing body of literature that specifically pertains to shared mobility which includes over 200 peer-reviewed articles

starting from 2014 and was therefore also an area of focus for the literature search. As with the two other areas of literature mentioned above, the objective of this review was mainly on those articles that attempt to define the term. The search yielded only three articles that attempted a definition of the term, however there were 51 others that were found to be relevant for this study since they either referenced previous definitions of shared mobility (notably the broad definition proposed by Shaheen, Chan, Bansal, & Cohen, 2015) or used the term to propose examples of solutions belonging to it. Most of these articles used the term freely without providing a definition or reference to a definition.

A brief history of the intersection between transport and digital technology: making sense of "new mobility"

Technology is an intrinsic part of transport: the invention of the wheel, the steam engine, the car, the aircraft, the space shuttle are all technological advances that have allowed humans to move further and faster. Despite this longstanding relationship, when the ICT industry started to develop in the 1950s and elements of ICT started to be used in the transport sector such as through vehicle loop-detectors and variable message signs, a more specialised link between transport and digital technologies was created. This formed what is known today as "Intelligent Transport Systems" or "ITS". Auer et al. (2016) traced the origins of ITS to the late 1960s when states, regions, academic institutions, and the automotive industry started to conduct new research on and deployments of ICT in the transport sector, specifically on its role in highway management. Masaki (1998) goes further back to the early 1930s, identifying broader technological developments such as the radar and the first electric traffic signals as the elements that provided the foundations for what today is currently known as ITS. Such differences in opinion regarding the origin of the concept reflect its broad nature, as ITS is generally understood to encompass most combinations of technology, communications and information applied in transport (ITS UK, 2016), and as such, can include diverse types of technologies including driverless vehicles, smart traffic light systems and electronic ticketing systems, amongst others. Despite this broad nature, ITS is generally understood to involve using ICT to improve the safety and efficiency of transport systems (Chowdhury & Sadek, 2003), and as a way to improve their operating capacities (Auer et al., 2016). ITS is, therefore, mainly concerned with those who interact directly with transport systems (e.g. operators and users), and less focused on pursuing broader societal goals such as sustainability (Levine & Underwood, 1996).

From the early 1990s, the term "smart mobility" has also been used to denote more specific interactions between these two sectors. This term stems from the development of the concept of "smart cities" (Benevolo, Dameri, & D'Auria, 2016) and before this from the concept of "smart" or "smartness", which generally denotes the use of technology to change how humans interact with the world (Brenner, 2007). Defining smart mobility or smart cities is complex, as the concepts are "fuzzy" and inconsistent (Albino et al., 2015), or "used as evocative slogan(s)" that lack substance and context within the sustainable transport sector (Papa & Lauwers, 2015, p. 543). Furthermore, smart can mean different things to different stakeholders, including the transport industry, governments, and academia, making it a difficult term to work with (Mosannenzadeh & Vettorato, 2014). Multiple authors have tried to come up with a single definition for smart mobility (Lyons,

2018; Mosannenzadeh & Vettorato, 2014; Nam & Pardo, 2011). Although definitions differ on some points, they tend to agree that the concept of smart mobility involves technological components (similar to ITS) but also goes beyond technology, as it is also concerned with improving sustainability goals, whether these are environmental, economic or socially related. Other characteristics of smart cities and smart mobility identified in the literature include the fact that smart cities forcibly lead to a new category of "smart citizens" (Vanolo, 2014) whose active participation and buy-in of the smart city concept is needed to fulfil its social and environmental promises, as well as smart governments (Nam & Pardo, 2011) which are seen as fundamental to the implementation of smart city initiatives.

Other authors have proposed taxonomies to help identify transport solutions that belong to smart mobility (e.g. Benevolo et al., 2016; Cledou, Estevez, & Soares Barbosa, 2018). As with the definition attempts, these taxonomies have fundamental differences between them, for example Benevolo et al. (2016) take a wide approach to smart mobility that includes solutions that could benefit from ICT such as bike lanes and park and ride facilities, while Cledou et al. (2018) narrow their scope to solutions that exclusively include ICT as a fundamental element such as journey planners and traffic monitoring. These examples add further evidence to support the suggestion that the concept of smart mobility is fuzzy and lacking in clarity, and that there is a lack of consensus on its scope (Garau, Masala, & Pinna, 2016). These taxonomies do however agree on four core elements of smart mobility solutions: their use of ICT, the importance of people and communities (through for example their participation in smart mobility processes), the acknowledgement of the importance of public institutions as promoters, users and/or beneficiaries of smart mobility, and finally, the goals or potential impacts that smart mobility might have on sustainability goals.

Another term which brings together the worlds of ICT and transport and has been widely adopted in the transport research community is Mobility as a Service or MaaS. This term first appeared in the literature in 2011 and searches in Scopus and Web of Science demonstrate a growing number of publications starting in 2015. MaaS has been defined as "buying mobility services based on consumer's needs instead of buying the means of mobility" (Kamargianni, Li, Matyas, & Schäfer, 2016), and as such refers to an innovation in the way users meet their mobility needs, rather than to a new technological development (e.g. a new invention). MaaS includes a suite of different technologies and services bundled together that allow a user to seamlessly use multiple modes of transport under a single service or subscription (similar to a mobile phone contract) which includes a single interface, user information, payment and infrastructure (Finger, 2015).

Similar to smart mobility, the idea of MaaS promises sustainability (Surakka, Härri, Haahtela, Horila, & Michl, 2018) and acknowledges the importance of taking into account stakeholders beyond only those who interact directly with transport systems (Jittrapirom et al., 2017). While some of the core enabling technologies of MaaS can be categorised under ITS (such as e-ticketing systems), the fact that its definition explicitly mentions other stakeholders as beneficiaries of its services actually brings the concept closer to that of smart mobility. Where MaaS differs from ITS and smart mobility is that it proposes a change in the way transport services are consumed, as MaaS implies moving away from ownership of the means of transport (e.g. owning a car, bicycle,

scooter) to a world where being able to access modes of transport as needed becomes the norm (Jittrapirom et al., 2017). This shift reflects a fundamentally different way of understanding the interactions between ICT and transport that smart and ITS proposed, as technology under MaaS is understood not only as a means to improve the operation of transport systems (like ITS), or as having impacts beyond its direct sphere of influence (like smart), but as an enabler of changes in how users understand and consume transport services. This change reflects what Papa and Lauwers (2015) call a "demand-" or "consumer-" centric innovation. The consumer-centric ICT + transport interactions proposed under MaaS are therefore markedly different to the techno-centric innovations of ITS – which see technology as a tool that improves transport service delivery – as MaaS implementations take into account the needs and active role of consumers, therefore tailoring technological solutions to fulfil those needs. In other words, under MaaS users of transport system are no longer seen as passive stakeholders that receive innovations; they are now becoming active participants in and leaders of technological transformations and shape how they are designed and deployed. Examples of these innovations include using and sharing transport modes that were previously personally owned (e.g. cars, bicycles, scooters) and providing consumers with data that was once inaccessible to them such as new routing and mode options, empowering them to make active decisions when consuming transport. A notable drawback of this consumer-centric evolution of technological transport services that has been noted by some authors is that users are increasingly seen as consumers that should be encouraged to use the service as much as possible since the financial returns of MaaS companies depend on higher use (Docherty, 2018). While increasing mobility is not necessarily a negative issue, it evokes notions of citizens surrendering their will to consumerism and capitalistic interests (Papa & Lauwers, 2015).

Other authors have also noticed changes in the relationship between technology and the transport sector in recent history, leading them to propose terms of their own to define them. Sperling (2018), for instance, argued that the mobility sector has seen an uptake in the pace of innovations in the past decade, called the "3 revolutions": shared, electric and autonomous vehicles. Canales et al. (2016) conducted a global survey of transport sector innovations and proposed the term: "new mobility services" which, in addition to the three revolutions, include a fourth element of new sources of data to support planning decisions. Furthermore, there are other authors who take a more literal approach when using terminology to define these innovations by using terms such as "innovative mobility services" to encapsulate any ICT innovation in mobility (Fioreze, de Gruijter, & Geurs, 2019). While the technologies and services proposed under these terms could be englobed under either ITS, smart mobility, or MaaS, the fact that they emerged shows that there is still no consensus on a single definition that encompasses all interactions between ICT and transport (Schade, Krail, & Kühn, 2014).

Defining the "sharing economy"

While the transport sector is seeing changes in the way its services are being accessed (from owning to consuming), this transformation is not exclusive to the sector – it is also found in a broader social movement known as the "sharing economy" or "collaborative consumption". The concepts of the sharing economy or collaborative consumption

denote a shift from owning to accessing goods and services such as vehicles, housing and even short-term labour ("gig work") (Acquier, Daudigeos, & Pinkse, 2017). Other terms that are less frequently used for the same concepts are "access-based consumption", "the mesh", "connected consumption" and "collaborative economy" (Codagnone & Martens, 2016). Although most of these terms have been used interchangeably in the literature, small differences distinguish them. Collaborative consumption, for example, is defined as a "set of resource circulation systems which enable consumers to both obtain and provide (…) resources or services through (…) other consumers or a mediator" (Ertz, Durif, & Arcand, 2016, p. 15). Under this definition, activities such as buying a car from a used-car dealership, selling old video games to a reseller, and even bartering, lending, and gift giving would all be considered part of collaborative consumption. A notable fact from this definition is that technology is completely absent, though it is not precluded. Botsman and Rogers (2011), who are generally accepted as popularising the term collaborative consumption, do include ICT in their definition, which shows how the scope and mechanisms of this term are not widely accepted. The term "sharing economy" is also frequently used in the literature. Walker (2015) traced its origins to historical and existing sharing practices such as local exchanges (e.g. tool sharing within neighbourhoods) or timebanks (Walker, 2015, p. 15) which highlights that the concept of sharing is not new, but that there are now new services that use mobile technologies to expand the scope of these original sharing activities (regular sharing) and therefore a new concept of a sharing economy has emerged.

One of the main differences between regular sharing and the sharing economy is the use of technology, as the sharing economy relies on "technological infrastructure", "digital connectivity" or "digital platforms" (Acquier et al., 2017; Richardson, 2015; Schor & Fitzmaurice, 2015). While regular sharing has existed for a long time, the advent of ICT has helped change the nature of sharing, allowing strangers (instead of acquaintances or people within a local community) to now exchange goods, services and create new social connections through digital platforms (Schor & Fitzmaurice, 2015). Another important difference between regular sharing and the sharing economy is that applications that fall under this concept can (and often do) involve corporations, rather than individuals, that carry out these activities in order to seek a profit (Belk, 2014).

While there are clear differences between sharing and the sharing economy, this latter concept is still not widely accepted nor defined (Acquier et al., 2017). For this reason, some authors have proposed typologies and taxonomies to define services belonging to the term sharing economy (Acquier et al., 2017; Schor & Fitzmaurice, 2015). Most of these taxonomies agree in the fact that sharing economy services support an increased utilisation of underutilised goods and services by recirculating surplus goods (e.g. increasing utilisation of cars which would otherwise be parked through services like Zipcar or Turo) and that they use digital platforms to facilitate this activity. They differ however in a basic characteristics of these services which is their commercial nature (e.g. for or non-for profit) (Acquier et al., 2017; Schor & Fitzmaurice, 2015). In that sense, Schor and Fitzmaurice (2015) proposed that the two distinct characteristics of solutions that belong to the sharing economy are their "market orientation", which can be for or not-for profit, and their "organisational type" (peer-2-peer or business-to-peer) (Figure 2).

		Organization	
		Peer-to-Peer (P2P)	Business-to-Peer (B2P)
Market Orientation	Non-Profit	P2P Non-Profit Sharing e.g. Food Swaps, Time Banks	B2P Non-Profit Sharing
	For-Profit	P2P For-Profit Sharing e.g. Relay Rides, AirBnB	B2P For-Profit Sharing e.g. Zipcar

Figure 2. Typology of services that fall under the term "sharing economy" with examples (Schor & Fitzmaurice, 2015).

How has shared mobility been defined so far?

As with the terms "smart mobility" and "sharing economy", the definition of shared mobility is still a debated subject. Overall, there is a lack of literature that focusses on proposing a definition or on identifying the boundaries of the term. (Le Vine & Polak, 2015, p. 407) declared the topic of terminology in shared mobility "vexed" and acknowledged that there is no consensus on its boundaries. As with the concept of "smart", a lack of engagement with the boundaries of a term can lead to different interpretations by different users, diminishing its usefulness. In the literature reviewed sometimes shared mobility is understood literally as the "sharing of mobility resources" (Santi & Ratti, 2017, p. 329). The authors mention sharing a ride (e.g. carpooling) or sharing a vehicle (e.g. car-sharing) as examples of shared mobility, but do not introduce a more explicit definition. Other authors use the term "shared mobility" in their research, but do not provide a definition (e.g. Muñoz & Cohen, 2017). This seems to be the most common approach in the literature, as the term is freely used without providing any explanation as to what it means, leaving its interpretation to the reader (e.g. Clewlow, Mishra, & Center, 2017; Laporte, Meunier, & Wolfler Calvo, 2015; Zhang, 2018, amongst many others). Some authors (e.g. Furuhata et al., 2013; Lembcke et al., 2020) focus on classifying subsets of shared mobility such as "ridesharing", and accept that these form part of shared mobility, but don't connect their classifications to the broader term. On the other end of the spectrum, Shibayama and Emberger (2020) list some shared mobility services in their attempt to create a taxonomy for new mobility services. While comprehensive, their exercise focuses on identifying the types of innovations that allowed these services, not on their inherent characteristics or what defines them as being part of shared mobility.

From the literature reviewed, only three sets of authors proposed an explicit definition of the term: Shaheen et al. (2015, p. 4) define it as "the shared use of a vehicle, bicycle, or other mode", while Santos (2018) and Machado, de Salles Hue, Berssaneti, and Quintanilha (2018) each proposed a taxonomy to delimit its boundaries. Santos' taxonomy includes four models of shared mobility implementations (see Figure 3), while the one proposed by Machado et al. (2018) includes five: (1) carsharing, (2) personal vehicle

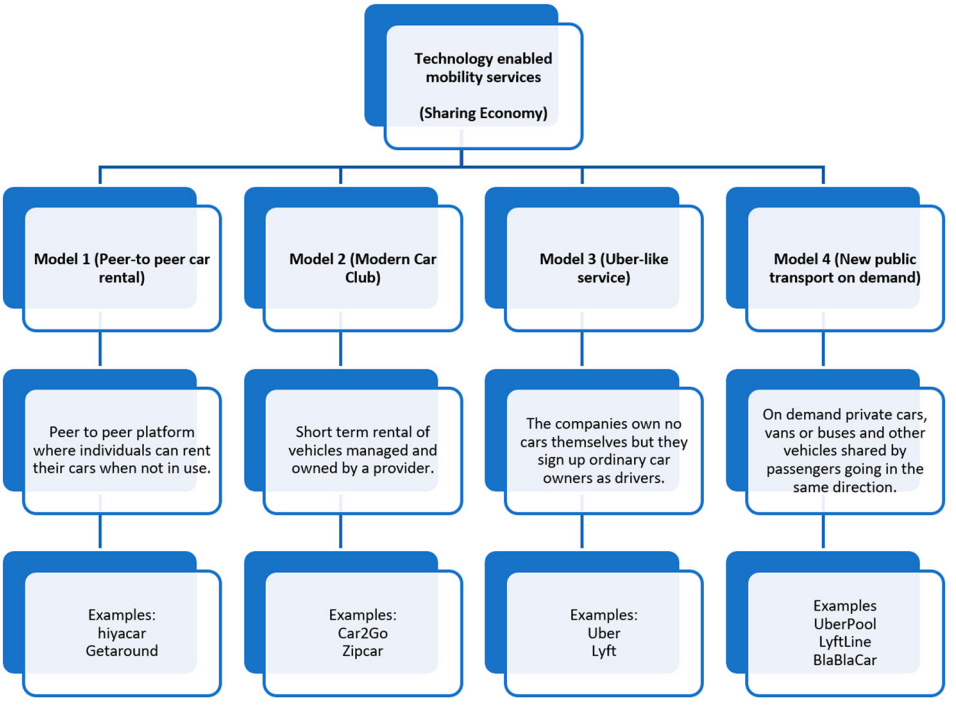

Figure 3. A taxonomy of shared mobility models proposed by Santos (2018).

sharing, (3) bikesharing, (4) ridesharing, and (5) on-demand ride services. Although all three definitions acknowledge that "shared use" is a central element of shared mobility, they don't agree in the sharing of services as a part of the term, especially since the first two definitions have a marked focus on the sharing of vehicles, not sharing services. Additionally, Santos' taxonomy exclusively focuses on cars or larger motorised vehicles – excluding other potential forms of shared mobility such as bicycles or e-scooters, which Shaheen et al. do consider in their definition. All three sets of authors also acknowledge the importance of technology, in particular mobile phones and the internet, as enablers of shared mobility.

Outside of academia, other stakeholders have also delved into the topic of shared mobility and proposed their own definitions. The U.K. government for example, defines shared mobility as "models based on shared ownership or use of vehicles" that are "enabled by digital platforms" (Department for Transport, 2018). The US government has at least two different definitions used by agencies that have oversight over the transport sector: the Federal Transit Administration defines it as "shared transportation services" that include asset sharing, service sharing and even commercial delivery (US FTA, 2016); and, The Department of Transportation defines it as the shared use and access of vehicles (US DOT, 2016), but does not explicitly mention service sharing nor delivery. Unlike the U.K.'s definition, the US ones do not include shared ownership as an element of shared mobility.

Moreover, other types of organisations have also proposed their own definitions. The "Shared Used Mobility Center", a public-interest organisation based in the U.S.A. dedicated to sustainable mobility, defines shared mobility as "transportation services and resources

that are shared among users, either concurrently or one after another" (SUMC, n.d.). Under this definition, public transportation and taxicabs are forms of shared mobility, meaning that the ICT aspect is not essential to their understanding of the concept. After an effort of external consultations with academia, industry and governmental organisations as well as a literature review, SAE International published a standard called "Taxonomy and Definitions for Terms Related to Shared Mobility and Enabling Technologies". Here, shared mobility is defined as "the shared use of a vehicle, motorcycle, scooter, bicycle, or other travel mode; (…) that provides users with short-term access to a travel mode on an as-needed basis" (SAE International, 2018, p. 7). Again, this definition does not explicitly mention the need for ICT, though the title of the standard implicitly acknowledges technology as an enabler of shared mobility (e.g. "shared mobility and enabling technologies"). As with most of the previous definitions, there is no explicit mention of sharing services, only sharing vehicles which also excludes the sharing of other mobility assets, such as parking spaces or bicycle corrals, which could be considered as shared mobility services if they are enabled by ICT. Other authors have identified examples of shared mobility implementations such as shared bicycles, airplanes, and more recently electric kick-scooters (e.g. Laporte et al., 2015; Raviv & Tzur, 2016; Shaheen, 2016). Yet, these studies do not provide definitions of shared mobility mainly due to their focus on specific topics within each of those modes (e.g. assessing sustainability implications of shared bicycles, operational aspects of carsharing, or social motivations for sharing modes).

Despite these studies, and perhaps owing to the nascent nature of the field, there is yet no clarity on the impacts on sustainability of shared mobility. With respect to environmental sustainability, some forms of shared mobility such as car-sharing (US)/car-clubs (U.K.) or bike-sharing have the potential to achieve CO_2 reductions because their use might result in users postponing the purchase of a private car or reducing car usage, whilst others such as ride-hailing (e.g. Uber, Lyft) might have a negative environmental impact by inducing users to take more trips, or reduce their share of trips taken by more sustainable modes such as public transport, walking and cycling (Nijland, Van Meerkerk, & Hoen, 2015; Shaheen & Chan, 2016). When looking at the social pillar of sustainability, shared mobility in the form of ride-hailing has been shown to improve access to opportunities for disadvantaged communities such as Black and Latinx communities in Los Angeles (Brown, 2018); but it has also been shown to be used mostly by higher income populations (Kodransky & Lewenstein, 2014), which shows that the potential social benefits are not distributed equally and are context specific. While these are just a few examples, due to the differences in the nature and types of shared mobility services that exist today, and considering that many of these services are privately led – which means that accessing data to quantify their impacts is difficult – it is still hard to assess shared mobility against sustainability outcomes (Santos, 2018).

The "sharing economy" meets "smart mobility": a working taxonomy of shared mobility

Why a taxonomy?

While definitions are undoubtedly useful tools to create a common understanding of a term or concept, as shown in the previous section they can be ambiguous, open to

interpretation, and easily contested. Classifying elements that fall under a specific concept might be a better way to create this needed common understanding, as classifications are less ambiguous, can be more exhaustive, and delineate clearer boundaries within what is inside and outside the scope of a term or concept. Bailey (1994) argues that without classifications, there can be no conceptualisation, reasoning, or data analysis of research topics. Particularly for shared mobility, a lack of a clear delineation of the term can lead to different stakeholders using it to refer to different shared mobility solutions. Furthermore, a classification can help describe a phenomenon, making it less complex, and therefore advance the study of its relationships to other objects and topics (Bailey, 1994).

In the realm of classification, two methods stand out: taxonomies and typologies. The difference between these two lies in the fact that typologies classify objects (social or physical) into ideal conceptual categories or mental constructs, while taxonomies classify objects according to their inherent characteristics or properties (Smith, 2002). Since typologies depend on ideal mental constructs, they suffer from the same drawbacks as a definition. Shared mobility as a concept already exists and has been implemented in real-world applications, and therefore finding common and uncommon characteristics within existing applications might be a better way to classify and define the already accepted, yet implicit boundaries of the concept. For this reason, the following section proposes a taxonomy of shared mobility using existing examples and implementations to identify their basic shared characteristics.

A taxonomy for shared mobility

Since the building blocks of shared mobility are found both within the sharing economy and the ICT + transport interactions denoted (amongst others) by smart mobility, this section builds upon these two tranches of literature to propose a taxonomy and boundaries of shared mobility.

Shared mobility can be framed within the transport literature as being part of the concepts of "smart mobility" or "Mobility as a Service", and to a lesser extent as part of the broader concept of "ITS". As discussed in the previous sections, one of the main components that these three concepts have in common is that they are all enabled by ICT. This inclusion of ICT as a core element of shared mobility implies that only applications that are enabled by, and therefore intrinsically linked to ICT, can be considered as being part of shared mobility. This means that, while there are services that have existed for several years (such as public transport, regular taxi services, car rentals or even casual asset sharing between acquaintances, amongst others, which could be understood as being part of shared mobility), the fact that their existence is not dependent on ICT, rules them out as belonging to the concept of shared mobility. Using this same logic, services such as ridesharing (analogous to public transport), ride-hailing (analogous to taxi services), or car sharing (analogous to car rentals) can only happen because they are enabled by ICT, and particularly, mobile phones, digital/social platforms, and internet connections, and therefore they belong to the concept of shared mobility. This does not mean, however that their non-ICT counterparts could not benefit from technological innovations, as they indeed have done, but simply that their existence is not dependent on these and are therefore not considered as belonging to the concept of shared mobility.

The other element that both "MaaS" and "smart" have in common is the fact that their objectives go beyond the inclusion of ICT as a way to facilitate or improve the use of transport systems (as is the case with ITS); these concepts incorporate and are concerned with the broader implications and requirements that these ICT/transport interactions will have on people, institutions and sustainability, and furthermore explicitly require that these are present. As noted above, notably the sustainability element is one that has been an interest of research around shared mobility. This however is not a unique or a distinguishing characteristic of shared mobility, as this recognition could also be true for other forms of transport such as the examples given above. What this characteristic does, though, is provide a link between the concepts of "smart" and the "sharing economy", as both of these recognise the need to consider broader social implications, in particular the relevance of people and institutions in the fulfilment of their sustainability promises.

Using this link between the worlds of the sharing economy and smart transport, an adapted taxonomy of Schor and Fitzmaurice's (2015) sharing economy typology is presented in Figure 4 that uses existing shared mobility services to identify its most basic characteristics, which are their transaction type (whether they are peer-2-peer, business-2-consumer, or government-2-consumer), their market orientation (for- and not-for- profit) and the type of solution they propose (sharing of assets or sharing of services). The taxonomy also updates Schor & Fitzmaurice's typology by proposing the new category of government-2-consumer, as there are shared mobility services that can be government-led, like docked bikesharing systems. It also updates the terminology to "consumer" instead of "peer", to bring it in line with the literature of MaaS and to acknowledge the commercial nature of most of these services.

The choice of terms which can be seen above in the eight distinct types of shared mobility implementations were selected based on commonly used terminology in the literature where possible, and where not, new terms were proposed. It is worth noting that the examples of usage of specific terminology might have different meanings in different geographies (e.g. car sharing and car clubs, as noted above), and for that reason the examples try to be as inclusive as possible to the authors' knowledge on these idiomatic differences. Table 1 below shows the term chosen, examples of where it has been used in the literature, and existing services that fall under each term:

Discussion and limitations

The taxonomy and clarification of terminology shown in Figure 4 and Table 1 above are intended to present a concise and bounded classification of shared mobility services that can be used by policymakers, private stakeholders and academics alike to ensure a shared and common understanding of solutions under this term. As shown in the review, shared mobility has been proposed as a potential solution to negative externalities in the transport sector such as environmental impact, congestion, and lack of access. Lacking a shared understanding of what is "in" and "out" of the shared mobility term could for example lead to policymakers bundling solutions that achieve opposite outcomes when it comes to solving these externalities; a lack of broadly accepted definition of classification could have social implications, as the term has been and continues to be used for policy formulation. Other authors (Bailey, 1994; Smith, 2002) have argued for the benefits of classifications and definitions such as reducing complexity and creating

			Transaction type		
			P2P (peer-2-peer)	B2C (business-2-consumer)	G2C (government to consumer)
Market orientation	Non-profit	Asset	N/A	*(4)* Public vehicle sharing[1]	*(7)* Public vehicle sharing
		Service	*(1)* Vehicle pooling	N/A	*(8)* Public ride sharing
	For-profit	Asset	*(2a) P2P vehicle-sharing* *(2b)* P2P mobility asset sharing	*(5a) Private vehicle-sharing* *(5b) Private* mobility asset-sharing	*N/A*
		Service	*(3) Ride-hailing/sharing*	*(6) Microtransit / demand responsive transport*	*N/A*

Figure 4. A taxonomy of shared mobility services.

Table 1. Proposed terms and examples of their usage in the literature and in existing services.

Proposed term (corresponding to Figure 4)		Examples of its usage in the literature		Examples of existing services
1	Vehicle pooling	Car pooling	Ben-Akiva and Atherton (1977), Montero (2019), Teal (1987)	Mobicoop
		Van pooling	Kircher and Wapensky (1978), Maxwell and McIntyre (1979)	
2a	P2P vehicle sharing	P2P car sharing	Shaheen, Cohen, and Jaffee (2018)	Getaround, Turo, Spinlister
2b	P2P mobility asset sharing	P2P parking sharing	Lai, Cai, and Hu (2021)	JustPark
3	Ridehailing/ridesharing	Ridehailing/ridesharing	Rayle, Dai, Chan, Cervero, and Shaheen (2016), Shaheen (2018), Wang and Mu (2018)	Uber, Lyft, Via, RideAustin
4	Public vehicle sharing	Public bike-sharing	Parkes, Marsden, Shaheen, and Cohen (2013)	HealthyRide
5a	Private vehicle sharing	Car sharing/car clubs	Kent and Dowling (2013), Novikova (2017), Wagner and Shaheen (2016)	Car2Go, Zipcar
		Bike-sharing	Lan, Ma, Zhu, Mangalagiu, and Thornton (2017), McKenzie (2018)	Mobike
		Scooter-sharing	Clewlow (2018)	Lime, Bird
5b	Private mobility asset sharing	Parking space sharing	Xiao, Zhang, and Yan (2009)	SpotHero
6	Microtransit/Demand Responsive Tranport (DRT)/On-demand transit	Microtransit/Demand Responsive Tranport (DRT)/On-demand transit	Brake, Nelson, and Wright (2004), Chebbi and Chaouachi (2015), Wilhelms, Henkel, and Falk (2017)	Chariot, Bridj
7	Public vehicle sharing	Public bike-sharing (PBS)	Parkes et al. (2013)	Velib', Capital Bikeshare
8	Public ride sharing	On-demand public transport	Ronald, Yang, and Thompson (2016)	Kustuplus, GoSuttonBus

Note that the column "Proposed term" corresponds to the taxonomy presented in Figure 4.
Mobicoop in France is a community run site that facilitates connections between drivers and passengers without a commission and survives on donations.

analytical frameworks that allow the study of subjects, something which is needed in the topic of shared mobility as it is a fast-evolving one that requires additional understanding of its implications for society.

The choice of the categories of "market orientation", "transaction type" and "asset/service distinction" is based on observable characteristics of existing services that have mostly implicitly been understood in the literature to be part of shared mobility. As noted in the discussion of classification methods however, the choice of categories for both taxonomies and typologies is a subjective process that might overlook additional common characteristics of these solutions. While there is no easy solution for this, the choice of categories was based not only on previous literature, but also on the authors' academic and industry experience of working with public and private sector stakeholders on different shared mobility solutions. Additional work to improve on this proposal might include conducting a survey of practitioners to identify additional categories. Furthermore, as noted in the review of the literature of ICT + transport and sharing economy, these concepts are "fuzzy", which creates a difficulty in building on top of them to propose a definition. Using a taxonomy however, since taxonomies use observable characteristics of a phenomenon, reduces the risk of proposing a definition under "shaky foundations".

In addition to identifying these observable characteristics of shared mobility, the review of the literature of ICT + transport and the sharing economy conducted allowed to identify what are described as "intrinsic" characteristics of shared mobility implementations. These include the use of ICT and a broader concern for people, institutions, and sustainability. The literature reviewed to reach these conclusions was undoubtedly limited given how expansive these bodies of literature are. The review therefore focused on those papers that had explicitly set out to provide a definition and might therefore have left out some that didn't try to define the terms but might have helped in identifying other characteristics. The current paper should therefore be read as an expansion to the *definition* literature on the topic of shared mobility, and not as a metareview of the complete set of literature that underpins the concept.

When looking at the proposed taxonomy it becomes evident that most shared mobility services are being deployed by private sector stakeholders. Furthermore and as noted by authors such as Sperling (2018), these developments have sped up in recent years. This presents a challenge to the exercise undertaken for this paper, and in particular the choice of using a taxonomy instead of a typology: the taxonomy is based on observed characteristics of existing shared mobility services, but the sector is very dynamic and new solutions might emerge in the near future. In fact, as the research for this paper was being conducted, scooter sharing became ubiquitous in many cities around the world, but had the paper been written only two years ago, that solution might not have been included. While the authors have no control over the adoption of this taxonomy in such a dynamic space (e.g. there is no way to future-proof the taxonomy), the choice of categories was made in such a way that other endogenous characteristics of possible future shared mobility solutions such as the type of shared vehicle or asset are irrelevant, and only the more permanent characteristics can be used to identify a shared mobility solution (e.g. in our current economic system there can only be for profit or non-for profit organisations, and that will remain regardless of new technological innovations in the mobility space). An example of this might be how the discussion

around the future of automation in cars has seen some authors proposing that these vehicles should operate under a shared mobility model to reduce the exacerbation of private car ownership. If using this proposed taxonomy, such a solution could be classified as a for-profit, B2C, service (Narayanan, Chaniotakis, & Antoniou, 2020).

Conclusion

There seems to be a growing interest in the interactions between technology and transport in the extant literature, however the understanding of shared mobility as an element of these interactions is still ambiguous. While the benefits of shared mobility have been asserted by both private and public sector stakeholders, a lack of a broadly accepted and shared definition of the term leaves the evaluation of its impacts on sustainability to individual interpretation. Furthermore, the review showed that while there are different assumptions on the potential for shared mobility services to support sustainability goals, the complexity and range of different motivations by multiple stakeholders might be the driving force for these services, and therefore more evaluations of their real impact are needed. The taxonomy proposed by this paper is meant to help stakeholders from the public, private and academic communities reach a common understanding of what solutions are encompassed within the term shared mobility, and therefore remove an initial barrier when using the term. The proposed taxonomy also helps in bringing order and reducing the complexity of the universe of shared mobility solutions, by clearly delineating and bringing the different terms and solutions that exist and have been defined in the literature under a single framework.

Realising the importance of concretely defining the concept of shared mobility, this paper reviews the two bodies of literature that underpin it: (1) the interactions between ICT and transport, and (2) the broader concept of the sharing economy. Unlike previous attempts at defining shared mobility, the proposed taxonomy explicitly acknowledges the fact that not only vehicles can be shared, but also other types of mobility assets and services. Apart from the creation of the taxonomy, the other main contribution of the paper to the literature is the identification of baseline concepts that are proposed to be intrinsic to the existence of shared mobility solutions; notably that their existence is dependent on ICT, and that they acknowledge broader social implications, in particular the relevance of people and institutions in the fulfilment of their sustainability promises. The identification of these concepts allows to differentiate the solutions that fall under shared mobility from older concepts of sharing (such as public transport) and from other applications of technology in the field of transport (such as ITS).

Furthermore, and building on previous work by Schor and Fitzmaurice (2015), the taxonomy proposes that shared mobility services can be organised based on observable and empirical characteristics of existing solutions, notably their market orientation (for- or not-for profit), their transaction type (peer-2-peer, business-2-consumer, or government-2-consumer), and their solution type (asset or service). By using empirical characteristics of shared mobility solutions, future developments in this fast-evolving space can be accommodated into the taxonomy without the need for major revisions, making this taxonomy a potentially foundational piece in the future study of shared mobility.

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