Can multi-modal integration provide enhanced public transport service provision to address the needs of vulnerable populations?

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ABSTRACT

This paper examines the challenges associated with provision of effective transport services to the 'mobility poor' and identifies potential methods to overcome these challenges. "Prioritised area" types representing a mix of geographies and population types, in addition to the multi-dimensional influences of mobility access, equity, and provision are identified, based upon the literature reviewed and information from transport providers, authorities and agencies. Supply side considerations are reviewed before turning to the potential ways for mitigating identified gaps in the requirements of prioritised areas, with particular reference to new models of transport service provision, technological solutions, and various modal and multi-modal solutions. The findings show that more flexible and integrated public transport solutions are being explored by cities, regions and service providers to address the constraints of more conventional models. Flexibility in such services is in the form of geographic, temporal, or vehicle flexibility. These are complemented by the opinion of experts as to the way forward for providing more tailored services for vulnerable users. Despite challenges, the paper identifies some promising service options for travellers in both rural and urban environments; however, any successful service must be underpinned by a robust, multi-modal transport network in order for that promise to be realised.

JEL classification: R420, R410, R400

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1. Introduction

Identification of transport users who are 'vulnerable to exclusion' is not a simple prospect. Myriad factors impact upon how well different groups of travellers are served by transport networks, including those associated with the person themselves, contextual factors such as the geographic and economic environment, and the existing multi-modal transport system. Compounding these influences are spatial and temporal dimensions of service, with particular considerations around how effectively the transport system is able to match users with their preferred destinations at times that are appropriate for undertaking desired activities.

In this paper, we draw on work completed as part of the EU-funded Horizon 2020 INCLUSION (Towards more accessIble and iNCLUSIve mObility solutions for EuropeaN prioritised areas) project to reflect on the challenges and opportunities associated with providing adequate and efficient transport services for vulnerable populations and areas, which we term "prioritised areas". In Section 2 we provide an extensive literature review to describe such areas with reference to area types; user segments; mobility options; transport infrastructure and service provision; key societal trends affecting mobility and accessibility (including first and last mile connectivity); inclusivity and equity; and the impacts (potential or experienced) of such trends on vulnerable users. This is complemented by a review of supply-side considerations in Section 3.

In Section 4, we use identified characteristics along with consideration of known practical concerns expressed by transport providers, authorities and agencies to identify a set of 15 "prioritised area" types that are representative of the multi-dimensional nature of vulnerability in transport. Of note is that these areas are designed to represent a mix of geographies and population types; in addition to representing the multi-dimensional influences of mobility access, equity, and provision. They are intended to demonstrate the complexities inherent in planning for effective transport services across heterogeneous populations and geographic areas. The requirements of prioritised areas are then aligned with an overview of potential ways for addressing or mitigating identified gaps with reference to new models of transport service provision and the additional incorporation of a range of technological levels and solutions. In this context we consider different modal and multi-modal solutions including demand responsive and flexible transport services and other shared transport solutions, improved passenger information, potential first- and last-mile solutions, and various aspects of Mobility as a Service (MaaS). The review considers how multimodal, as compared to unimodal, solutions have provided opportunities in their application. This review is complemented, in Section 5, with a review of expert opinions that add further context to identified considerations and suggest additional requirements for effective service provision.

The overall objective of the paper is to demonstrate the complexities associated with provision of effective transport services to the 'mobility poor', as well as identifying potential methods, and the relevance of multimodal solutions, to overcome these challenges. This objective is achieved via discussion of findings from the reviewed literature and expert input and examples of good practice, as well as an assessment of the suitability of different mobility interventions for addressing these challenges.

2. Background

The concept of 'transport poverty' is complex, with Lucas et al. (2016) identifying it as an overarching concept comprising: "transport affordability…– that is, inability to meet the cost of transport; mobility poverty – that is, the lack of (usually motorised) transport; accessibility poverty – that is, the difficulty of reaching certain key activities such as employment, education, healthcare services, shops and so on…; and exposure to transport externalities (Lucas et al., 2016, p. 354-355)." As reflected in Lucas et al.'s work, transport poverty is a multidimensional construct comprising elements related to geographic areas, individuals and households, and the existing transport network. While the identification of individual elements relating to each of these factors is necessary, it is often their interrelationships that provide a full picture of the scope of transport poverty experienced. In the following section, we present evidence from a review of the academic and practitioner literature undertaken using academic and general search engines and search terms such as 'mobility poverty', 'vulnerable populations', and 'mobility exclusion', as well as identifying relevant publications through reference to prior projects. We first address individual, household and geographic (demand-side) factors that may contribute to transport poverty, followed by a review of supply-side considerations.

2.1 Geographic area

2.1.2 Origin and Destination Geographic Areas

The residential and employment populations and relative densities of geographic areas have been noted as some of the primary influencing characteristics on mobility needs, services, and challenges (Chen et al., 2008; Schwanen et al., 2004; Stead and Marshall, 2001). While at times considered as a binary distinction of urban and rural, the use of the more nuanced OECD regional typology (complemented by further disaggregation based on accessibility – see Figure 1) provides clearer scope for distinguishing between the varying transport environments experienced, based not only on relative population densities, but also on characteristics of access to goods and services (Gray et al., 2008). Impacts of these characteristics on transport environments may include considerations such as:

- suitability of fixed-route versus demand-responsive or flexible public transport services, where, for example, Wang et al. (2015) found that Demand-Responsive Transport (DRT) is used more frequently by those who are disabled, travelling for work, or who live in less densely-populated areas (Mageean and Nelson, 2003; Wang et al., 2015);
- distance of travel or ease of accessibility to necessary goods and services through active means (such as walking or cycling); for instance, Saelens et al. (2003) found that residents living in communities with higher densities, greater connectivity, and more land-use mix had higher rates of walking/cycling than did residents from low density, poorly connected, and single land-use neighbourhoods (Saelens et al., 2003; Van Cauwenberg et al., 2012)
- patterns of mobility and access of area residents and visitors (e.g. tourists, business travellers, etc.) (Goncalves et al., 2017; Caulfield, 2015). It is important also to consider both the characteristics of the population areas served, as well as the destinations to which they are travelling, in order to ensure that the transport service(s) implemented are responsive to the needs and requirements of all journey segments. This leads to a distinction between origin and destination geographic areas.

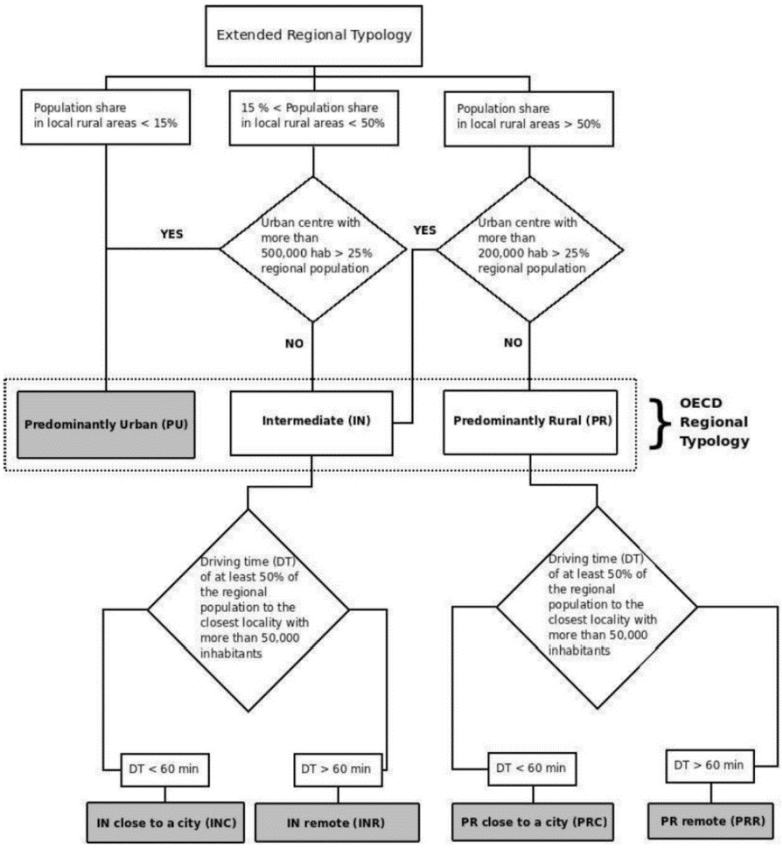

Figure 1: OECD Typology for Regional Geography (Source: Brezzi et al., 2011)

The distinction between the origin and destination geographic area distinguishes between where the population to be served resides, versus the area of primary destination 'pull' – for example, areas of service provision, leisure activities, or employment. Both are considered here, as they may have distinctly different characteristics according to the classification. Characteristics of origin and destination locations may also contribute to considerations of first- and last-mile connectivity, as transport options at one end of a trip may be unsuitable at the other (Rojas & Pyrialakou, 2018).

2.1.2 Topography

The topography of service areas will impact upon the suitability of different types of transport, both with respect to the implications for roadway geometry, as well as to the comfort and ability of travellers. The need to consider this is highlighted in a study by Daniels and Mulley (2012), which notes the importance of taking into account the topography of an area when planning and developing public transport provision. For example, where there is steep or hilly terrain with narrow lanes or tight curves, large capacity vehicles may be unable to cope with the required turning radii or roadway slopes (Ceder et al., 2015), necessitating smaller vehicles with lower capacity. The general lower population densities of such areas (Telbisz et al., 2014) is also a consideration, as these may make the use of conventional full-size public transport vehicles less financially viable (Daniels and Mulley, 2012). Steep or uneven terrain may also impact upon the suitability of walking or cycling as a mode choice (Guo and Ferreira, 2008), with Vandenbulcke et al. (2011) finding that much of the inter-municipality variation in bicycle use in Belgium is related to environmental aspects such as the relief (topography) as well as to traffic volumes and cycling accidents; although this may be addressed to some extent by e-bikes.

2.1.3 Climate

Climate, and associated weather, will impact both upon the types of transport interventions planned in an area, as well as the habits of users within those areas. While planners and transport operators often address the impacts of extreme or adverse weather on travel decisions (for example, Khattak and De Palma (1997) in a study of Brussels commuters found that more than one-quarter reported that adverse weather was either very important or important in changing their mode), it may be equally important to address the overall climate of an area when considering transport interventions. In a systematic review of the literature, for example, Böcker et al. (2013), concluded that, "Individual weather parameters have profound impacts on travel behaviour. Warm and dry weather conditions influence outdoor leisure activities and the use of active transport modes positively. Rain, snow, windy, cold and hot weather (above 25–30 ºC) often result in a switch from open-air to sheltered transport modes and decrease the number of visits to outdoor destinations. Departure times, travel times and routes are also influenced by these weather parameters (p. 85)." In addition to these considerations, areas that experience extreme variations in temperatures (such as very hot, wet summers and extremely cold winters with snow or ice) may also need to consider them when planning and implementing transport services, due to infrastructure and/or maintenance requirements.

2.1.4 Economic Vitality

The economic characteristics of an area will impact both upon the amount of investment that may be made into the local transport system, as well as on the travel behaviour patterns of its residents and visitors. It is important to note that definitions of deprivation may vary among the European states, notwithstanding common indicators proposed by bodies such as OECD, and these will need to be considered when describing the economic status of an area. Extensive transport investment may require access to immediate funds, as well as on-going financial security to ensure maintenance and upkeep of facilities, services, and physical and digital infrastructure in order to fully capitalise on the initial investment; considerations that should be taken into account during the decision-making process, as recognised by Mardani et al. (2016), who note that "sound socio-economic and environmental efficiencies are necessary for promoting effectual practices in transportation management (p21)." In addition, the economic characteristics of the population area served must be taken into consideration when allocating transport resources, to allow for recognition of factors such as: access to a private vehicle, working hours or other travel patterns, availability of funds for public transport fares, familiarity with the local transport network, and other characteristics that may reflect the overall economic status of the prioritised area (Di Ciommo and Lucas, 2014; Golub and Martens, 2014). A study by Lucas et al. (2008) focused on transport schemes in deprived areas and found users to be in support of transport provision that addressed their specific needs.

2.1.5 Population and Economic Trends

Consideration of the relative growth or decline in an area's population and economy may impact upon transport decisions made by areas as they look to address both immediate and more long-term needs. Alternately, transport infrastructure investment may stimulate economic development (and, in turn, population increase), providing certain other policy, investment, and economic factors are present (Banister and Berechman, 2001). While addressing the needs of the current citizenry is critical in designing effective transport networks, patterns of investment may impact upon future options, which should take into account the emerging mobility patterns evidenced by shifting or transitioning economies (for example, from an industry to service-based economy), patterns of migration, and relative wage rates. Population increases or decreases should also be taken into consideration, as these may impact, for example, upon transport coverage in an area (such as when

new developments are constructed outside of traditionally-served areas to house new residents) or timing and accessibility needs when areas are declining. Such trends, which encompass many of the considerations noted above, should be used to establish the emerging transport priorities of areas.

2.2 Individual and household factors

Vulnerability of people may be related both to individual characteristics and characteristics of the household and its interactions. Characteristics such as low income levels or place of residence (in a location with few non-car options available) with attendant forced car ownership characteristics may impact upon the household by restricting overall mobility levels or ensuring they are carried out in a way to minimise costs, while those such as age or physical or cognitive disabilities may have more specific impacts on individual members by restricting their access to opportunity. In this section, we review characteristics of both individuals and households that may impact upon transport vulnerability.

2.2.1 Individual Characteristics

At a time when the number of single-person households is growing worldwide (in the EU, for example, 34% of households were single-person in 2017 compared to 31% in 2010 (Eurostat, 2018), while the figure has risen from roughly 10% in 1960 to 24% in 2015 for Australia (Chamie, 2017)), it is often difficult to differentiate between characteristics of the individual that may impact upon access to mobility, and those of the household. However, while there is certainly overlap between the two, many physiological and other characteristics directly related to an individual will impact upon that person's ability to travel independently and easily, either individually or more broadly within the scope of the household.

Perhaps the individual characteristic most commonly considered as contributing to vulnerability is physical or cognitive disability, which may both limit a person's modal choice and constrain their ability to access opportunity. Of note, however, is that not all disabilities will have the same kind of effect on mobility. Wilson (2003), for example, states that:

> "Recent research in England (Campion et al, 2003) … suggests that "the difficulties caused by inaccessible transport are exacerbated for those respondents with visual impairments and disabled people without access to a car" (p6). DPTAC (2002a) also found that transport is a slightly more important priority for wheelchair users and visually impaired people in England and Wales... Research by RNIB highlights the inaccessibility of public transport and the pedestrian environment for visually impaired people in Great Britain (RNIB, 1999 & 2002). A National Autistic Society report (Broach et al, 2003) found that a lack of accessible transport options meant that some people with autistic spectrum disorders in England and Wales were confined to their homes, and that 'less visible access issues are being ignored as providers focus on making transport accessible for people with physical disabilities' (p. 8)."

Such findings reflect the multitude of considerations faced when working toward accessible transport, which may require a combination of mechanisms to address such varied challenges as visual impairments, cognitive limitations, and physical mobility limitations.

Furthermore, as highlighted by the 'From Exclusion to Inclusion' report (People and Policy, 1998), "For disabled people to be able to travel, and to travel with confidence, all aspects of the 'transport chain' must be accessible. The benefits of new vehicles and systems will be minimised, or lost altogether, if disabled people find that they cannot move easily and safely between transport modes. Disabled people also need accessible information on transport if they are to benefit from new vehicles and systems (p. 138)." While the impact of disability will likely extend beyond the individual

to the household, it is critical to keep the individual in mind when planning services and information sources.

Another characteristic of the individual that may significantly impact his or her travel is that of age. While there is some correlation between age and disability (as seen in Wahrendorf et al. (2013)), other factors with relevance to transport accessibility are related to considerations of age. For example, very young persons may be unable to travel independently without the support of a parent or guardian due to safety or security concerns, or lack of reasonable travel options (Crawford et al., 2017; Scheiner et al., 2019; Mitra and Buliung, 2015). For young adults, constraints may be less associated with safety and security, and more aligned with lack of access to travel options that will serve their needed origins and destinations at suitable times and at reasonable prices. Storey and Brannen (2000), for example, in a study of young people in the rural South West of England, found that "Over 40 per cent of those aged 15 to 16 say that transport issues influence their decisions about post-16 education. Limited public transport in rural areas means that those entering employment or training are restricted in where and when they work." Older persons may also face transport constraints resulting from a multiplicity of factors, including "…cognitive, psychosocial, physical, environmental, and financial influences (Webber et al. 2010, p. 444)." Characteristics of the home location may also contribute to mobility or lack thereof as a person ages, as reflected in (Chudyk et al., 2015; Buys et al., 2012; Kerr et al., 2012), and may also introduce further considerations regarding informational and physical requirements for multimodal trips.

Finally, the influence of gender is not inconsiderable in identifying and meeting individuals' travel needs, as evidence suggests that there are gendered differences in travel behaviours. Gordon et al. (1988) found that women generally have shorter work trips than men, that they undertake more non-work trips and in general have more complicated trip chains. This finding has been supported by a number of studies across a range of locations, including (Schwanen et al., 2001; Elias et al., 2015). However, there is some evidence that this pattern may be shifting, with Tilley and Houston (2016) finding that younger women were, in fact, travelling more than their male counterparts. Notwithstanding this trend, however, other considerations, in particular safety and security (Lynch and Atkins, 1988; Sham et al., 2012), need for joint trips (Chen and Akar, 2017) and tendencies to trip chain, are also especially relevant to women's travel behaviours and may influence choice of travel mode.

2.2.2 Household Characteristics

While the characteristics described above clearly have impacts on the individual traveller, their influence may also be felt at the household level. Having a member with characteristics of vulnerability may limit the travel choices of other household members, regardless of their own status. For example, parents or caretakers who are responsible for the transport of household members who are unable to travel independently may face constraints on available travel times or modes, which in turn will impact upon household-level travel decisions.

There are, however, also household-level characteristics that will more directly impact upon all members of the household and that may in turn directly impact upon vulnerability. Such household characteristics as socio-economics, migration, and employment status of household members will impact upon access to both services and information on services. In terms of socio-economics, both income level and occupation may impact upon travel choices. High-income households are more likely to have access to cars and to have opportunities to participate in non-obligatory activities (Dieleman et al., 2002; Buliung and Kanaroglou, 2006). In contrast, low-income households tend to have fewer available transport mode alternatives, often resulting in more limited time budgets for travel and lowered employment opportunities and in some cases forced car ownership (Currie and

Delbosc, 2013; Bocarejo and Oviedo, 2012; Buehler, 2011; Fan and Huang, 2011; Currie and Senbergs, 2007). In addition, traditional models of public transport service, which concentrate primary areas of coverage during peak hour times, may not adequately serve the needs of persons who work shifts, part-time hours or overnight (Kenyon et al., 2002; Sanchez et al., 2004; Ryley et al., 2014). The combined effects of these considerations contribute to the transport vulnerability of low-income populations and demonstrate that traditional models of transport service provision may not adequately serve this population.

Another household characteristic that has the potential for substantial impact upon transport vulnerability, but is currently relatively understudied, is that of migratory status. While domestic migration (such as rural to urban or city to city moves) may cause limited upheaval, it still requires access to and understanding of new transport networks and may have caused instability in supporting transport networks (such as both formal and informal ride-sharing). Intra-EU migration is perhaps more of a special case as it is more international than domestic but migrants are more likely to return home regularly. International migration, however, potentially introduces even more significant impacts upon households, due to a number of factors including economic circumstances, language barriers, and locations of housing availability. For example, Cebollada (2009) found that language was a key barrier to driving for non-EU in-migrants to Barcelona, as the theory test for licenses must be passed in one of the local languages. Such barriers may also impact upon access to public transport networks, as well, as information may not be available in understandable formats and concerns regarding transfer points may discourage participation.

2.3 Summary

The characteristics described above provide some idea of the complexity of considerations at play when developing transport systems that effectively serve both prioritised areas and vulnerable populations. While the initial overview has addressed these issues on individual bases, it is clear that interactions between the different characteristics will further exacerbate potential impacts on access to mobility. This is further compounded by supply side considerations, identified in Section 3. In section 4, we review a number of potential ways in which combinations of area attributes may impact upon the suitability of different transport offerings, particularly in the context of different user groups.

3. Supply side considerations

While geographic, household and individual factors are key considerations in transport vulnerability, government policies and regulations and operator practices also play a role in the relative accessibility or otherwise of transport options. Public transport financing generally relies on a mixture of farebox revenues (i.e. ticket purchases) and public funds (to meet the difference between operating costs and farebox revenue) (Ubbels et al., 2001). Most governments also provide funding to allow certain vulnerable groups to travel at lower fares for example, fare concessions for older people (this is discussed further below). The farebox recovery ratio (calculated as the percentage of public transport operating costs recovered through passenger fares (USDOT, 2019)) is generally lower for areas of low density, demand responsive travel, and areas where there are a high number of concessionary fare passengers (USDOT, 2019; Hyde and Smith, 2017). In the absence of significant government subsidies, or in cases where other services are not profitable enough to supplement low-profit routes, such considerations may make provision of transport services to vulnerable areas and users difficult to justify from a financial standpoint (De Jong et al., 2011; Ubbels et al., 2001). Such considerations are highlighted by Šeba (2017), who states: “However, less developed areas have to have integrated pricing and social policies towards the end users of urban transport, which often turns to be unsustainable in the longer period of time (p. 171).”

The integration of social policies is a key consideration in the supply of services, as many locations have local, state, or national policies that require the provision of services or discounts to vulnerable populations such as the elderly and those with cognitive or physical mobility limitations (see, for example, the United States' Americans with Disabilities Act (ADA[1]), the United Kingdom's older person's bus pass[2], and the Netherlands' Act on Equal Treatment of Disabled and Chronically Ill People[3]). While such requirements are often accompanied by financial support, the services they fund may be disjointed across geographic boundaries or journey types, leaving gaps in access (Hernandez and Dávila, 2016; Hine and Mitchell, 2017). Such issues may require attention in policy and funding mechanisms, particularly in relation to the need to deliver more connected services for different journey types across populations and geographies.

Integration of social policies becomes particularly relevant as locales become more engaged in efforts to better integrate transport planning, land use and access to social facilities and services. In some cases, planning for accessibility has been seen as an effective method to facilitate this integration, with Straatemeier and Bertolini (2019) reflecting on the use of 'Joint Accessibility Design' in two case studies in the Netherlands, finding overall benefits to awareness of the implications of transport planning on land use (and vice versa) as well as more integrated planning strategies. More focus on activities, rather than simply movement, may also be beneficial in this regard, particularly when addressing the spatio-temporal coverage of transport services in relation to access to opportunity, including such areas as healthcare, education, and work and social activities (Pucci and Vecchio, 2019; Guzman et al., 2017). A challenge to integration of public transport services may, however, arise when multiple service providers are competing in the same geographic area, or intersect at the boundaries of regions.

As demonstrated here, there are a number of challenges related to the provision and governance of transport services to the mobility poor. Funding and regulatory requirements, in particular, may limit the efficacy of disparate service providers, and leave gaps in coverage where the demand is inadequate for supporting profit-making public transport services. While integration of services and considerations of the dynamics between transport, land use, and activity requirements show promise for addressing these areas, constraints regarding funding models and competition may further exacerbate the challenges.

4. Prioritised area types

As part of the INCLUSION project, a number of area types were identified that are both representative of pilot locations within the project and offer insight into the complexities evident in providing equitable and inclusive transport services. Some of these prioritised area types include the following:

- Rural/remote area:
    - Deprived, hilly area in economic decline with an ageing population
    - Geographically isolated area with a seasonal economy and declining population
    - Flat area with an increasing population and mixed or improving economy
    - Accessible rural town with a growing young population and changing economy
- Peri-urban area:
    - Traditionally deprived area in economic growth, with an increasing population
    - Declining suburban area with ageing population

[1] https://www.ada.gov/
[2] https://www.gov.uk/apply-for-elderly-person-bus-pass
[3] https://www.government.nl/topics/discrimination/prohibition-of-discrimination

    - Accessible small town located in a hilly area with a stable population and mixed economy
    - Suburban area with increasing young population and stable economy
- Urban area:
    - Declining urban area with decreasing employment and population loss
    - Stable urban area with mixed employment
    - Growing urban area with increasing population and employment opportunities
    - Urban area with declining population, stable employment, and growing peri-urban areas
    - Very large urban area with stable employment and a growing population
    - Large flat urban area with declining employment and population
    - Urban area located in hilly area with stable employment and population

These area types demonstrate the complexity of characteristics that may be experienced when defining vulnerable area types, and indicate the need to better consider how transport services may be designed to address their complex interplay. In the following section, we highlight

4.1 Types of transport services offered

As noted above, there are a number of geographic, household and individual characteristics, in addition to other considerations such as personal preferences, that may limit use of private vehicles. Public transport is generally expected to fill in the gaps in these cases; however, traditional models of fixed-route services may not be the most preferred option in some of the area types identified above given the limitations observed in Sections 2 and 3.

In general, conventional public transport service provision consists of rail or road-based services, functioning on regular schedules and along a pre-defined and fixed route. While such service models may be considered reliable and easy to understand and require less pre-planning on the part of the traveller, they may also be limited in their responsiveness to change. Rail-based systems (either heavy or light), in particular, are geographically constrained as realigning their routes is a costly and time-consuming endeavour. Additionally, as noted by Hensher (2007) regarding the popularity of investment in light and heavy-rail systems, “Unfortunately, there are at least two major deficiencies…—namely the huge cost involved (in the billions, not millions) and the inability of such a solution to deliver more than a service to specific corridors, to the neglect of the needs of the systemwide network (p. 98).” Such services are often aligned to serve a particular area of economic focus, such as a city centre location, though McLeod et al. (2017) note that “The radial, central city emphasis of traditional hub-and-spoke PT networks, oriented to service central city commuters, has been the subject of much criticism within the literature over a considerable period (p. 226).”

With reference to the area types indicated above, such conventional systems may not offer the best public transport alternatives, as they may be unsuitable to serve remote or rural locations with limited population densities, and their operating models may be predominantly based around commuting patterns that do not fully align with the needs of the populations being served. They may also be deficient in their ability to adequately serve needs for trip chaining (Hensher and Reyes, 2000). Furthermore, in areas of population decline or growth, conventional public transport may not be able to respond to changing transport requirements in a timely and robust manner. As traditional 9-to-5 working day patterns decline (according to Eurostat (2018), in 2017, 20.3% of persons in the EU were in part-time employment, with youth unemployment at 16.8%), the need for more services outside of traditional peak commuting hours rises.

Increasingly, more flexible and integrated public transport solutions are being explored by cities, regions and service providers to address the constraints of more conventional models outlined above. According to Wright (2013), "Flexible Transport Services (FTS) are transport services which differ from conventional public transport in that they do not run on fixed routes. Rather, the route and timings are determined by user demand. The key characteristics are that they require pre-booking and operate on demand (p. 76)." The temporal requirements of such pre-booking may range from days or hours to nearly on-demand services. As indicated here, the flexibility in such services may come in the form of geographic, temporal, or vehicle flexibility, including the following examples:

- (Geographic) Route deviation services: These services "...operate along a route with fixed stops at generally fixed times, but may deviate from the route alignment to collect or drop off passengers who have requested the deviation (Yang, et al., 2016, p. 1770)."
- (Temporal) Demand responsive transport (DRT): DRT services "…provide transport 'on demand' from passengers using fleets of vehicles scheduled to pick up and drop off people in accordance with their needs. DRT is an intermediate form of transport, somewhere between bus and taxi which covers a wide range of transport services ranging from less formal community transport through to area-wide service networks (Mageean and Nelson, 2003, p. 255)."
- (Vehicle) Taxi services: The use of taxis (or other smaller vehicles) in place of conventional buses to provide services to more sparsely populated or geographically challenging areas is seeing an uptake in adoption due to benefits such as greater financial and environmental efficiency (Mulley and Nelson, 2009).

These and a number of other approaches to the provision of flexible transport services are growing in adoption, in part due to the technological advances that have provided better access to real-time information for both passengers and service operators.

While the above examples have been presented as stand-alone options, in reality many public transport systems will utilise a number of flexible elements to effectively serve their passengers while maintaining their financial stability. In addition, many of these services are expanding into multi-modality in recognition of the varying needs of currently underserved populations. While a 'one-seat' trip may be desirable (particularly for the elderly or those with physical or cognitive disabilities), integrating multi-modal options into public transport journeys provides scope for addressing many of the geographic and temporal constraints identified above. For a trip requiring travel from a remote or rural area, for example, taking a feeder service provided via taxi, car share, or bicycle/e-bike from the origin to a location along a main public transport route may open up options for those without access to a car, or who need to travel outside of peak travel hours. Such options may be beneficial for local transport operators, as they diminish the need to provide potentially expensive one-seat options from less economically viable locations, while still providing reasonable transport alternatives to vulnerable populations.

Recent explorations of Mobility as a Service (MaaS) posit methods to address these needs, through the integration of service offerings using a platform approach. As described by Kamargianni and Matyas (2017), MaaS "…aims to bridge the gap between public and private transport operators on a city, intercity and national level, and envisages the integration of the currently fragmented tools and services a traveller needs to conduct a trip (planning, booking, access to real time information, payment and ticketing) (p. 2)." Within an ideal MaaS ecosystem, multi-modal transport services are integrated into a common platform, with the ability to search, schedule and pay for trips, receive real-time updates across the journey, and be provided with alternative options should a journey be

disrupted. MaaS offers great promise in providing access to available service options for travellers in both rural and urban environments; however, it must be underpinned by a robust, multi-modal transport network in order for that promise to be realised.

5. Views from experts

While the above review has focused primarily on identifying the characteristics of populations, areas, and services that may contribute to mobility vulnerability and potential ways of addressing the resultant challenges, it is also critical to understand what mobility experts view as the key needs for offering more inclusive and accessible services. During the INCLUSION project, interviews and surveys were conducted with twenty-seven European representatives from academia and consultancy (9), user representatives (5), and transport operators or their trade associations (13). In these activities, interviewees were asked to identify what they view as the primary barriers, drivers and challenges regarding the provision of mobility services to vulnerable populations. Across the spectrum of interviews, the issue of complexity was a common theme, with multiple respondents indicating that balancing the mobility needs of vulnerable populations with factors such as funding and competing priorities contribute to the difficulty in providing adequate services. The multidimensional nature of challenges in service provision was also noted, with one operator observing that, "The multiplicity of places in which activities take place (living, working, studying and leisure) makes [it] difficult to have a competitive public transport network regarding travelling time. The need for transfers makes journeys longer, which sometimes cannot compete with private car, especially for trips from the periphery to the periphery." The inherent complexity of service provision was also highlighted by one academic researcher who stated "…if public transport is [to] be a suitable alternative for every one of these user groups, then we obviously need to consider all their needs. There may, however, simply be better and more efficient ways to serve certain user groups, which might make it 'okay' to exclude them from the public transport goals, while obviously making sure that their needs are being taken care of." Noting the competing demands of passenger needs, activity timing, and service models reinforces the discussion above and indicates the need for more attention to be given to how transport services are planned for and implemented.

Further supporting these conclusions, the following points were highlighted as core needs by the experts, with many indicating the ways in which multi-modal transport could serve the needs of vulnerable travellers if properly implemented:

- New service models should be explored. Integrated multi-modal services, such as those included in MaaS-style platforms and involving collaboration on the part of providers, should be more fully developed to take better advantage of existing and emerging services. This should include considerations beyond traditional bus and rail services, and incorporate walking, cycling, car-share, carpool, taxis, and other services.
- However, for the above to be effective better integration is needed. Dispersed populations and activities may reduce the likelihood that a one-seat trip is possible. However, service boundaries, technology limitations and competition may limit integration across modes and providers. Practices should be explored that allow integration as a multidimensional consideration, encompassing integration of services (including non-transport services), payment, and information.
- Multi-modal service offerings, such as those enabled by MaaS and MaaS-style services, should be developed following effective communication with vulnerable communities, particularly during planning processes. One passenger representative, for example, emphasised that their users are often presented with plans at the end of the process, rather

than being involved in their development. Undertaking a more inclusive, communicative approach to transport planning would allow for better, more efficient plans to be made that better serve the needs of the most vulnerable users.

- Planning of integrated services should take place with consideration of spatial and temporal coverage of services. Shifting employment patterns, changing family demographics, and more dispersed activity-based lifestyles require that better transport coverage is needed in terms of both space and time to ensure that all users have equal access to opportunities that may not fit into traditional working hours covered by conventional service models.
- For new models of service provision to be effective, better information sharing processes should be developed. In order to fully serve the needs of all users, transport information should be accurate and reliable, accessible from a variety of platforms (including digital and paper) and in a variety of formats (including, for example, images, text, and multiple languages).
- More financial and policy support is needed from local and national government. Financial concerns were regularly raised, both regarding the cost of transport for users and for the cost of providing service to vulnerable populations and areas. Cost was identified as a significant barrier for transport use, indicating that more considerations should be made for ways to offset its impact.

6. Conclusions

In this paper, we have identified a number of attributes that may contribute to transport vulnerability from the viewpoint of both places and people. The literature and analysis, supported by reflections from transport experts, shows a multidimensional and complex web of interactions that add to the difficulties of identifying problems in the first instance and the design and implementation of solutions.

The introduction of innovative, targeted and flexible solutions appears, from the perspective of prioritised areas, to be quite promising. However, they must be reliable, well-integrated, affordable, and have good information available for them to work for vulnerable individuals and households. Given, for example, safety and security concerns of female travellers, options that require a long wait to transfer or that require transfers in isolated locations will be unattractive, and unlikely to encourage use. Similarly, the availability of multi-modal options without adequate information integration will also be unlikely to fully meet the needs of vulnerable travellers – for example, persons with language barriers may struggle to reconcile information presented in different formats. Additionally, persons with mobility limitations or who are accompanying a vulnerable traveller need adequate information on the accessibility of intermodal transfers. Finally, information on transport disruptions and options for their mitigation must be available to travellers for them to feel confident in their journeys. While multi-modal journeys may address many of the issues identified above, they also introduce greater scope for interruption, delay or cancellation, which may impact upon subsequent trip legs. Allowing for integration of more flexible modes (such as bicycle trips, for those who are able, taxi rides or lift-sharing) into multi-modal trips may address some of these issues; however, only if there is adequate spatial and temporal integration (e.g. providing sufficient notice, for example via a journey planning app, for a traveller to be able to disembark from a bus trip where there is a rental bike service or liftsharing option available).

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Declarations of interest: none

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