Journal of Transport Geography 48 (2015) 61–75

Contents lists available at ScienceDirect

Journal of Transport Geography

journal homepage: www.elsevier.com/locate/jtrg

Transportation disadvantage impedance indexing: A methodological approach to reduce policy shortcomings

Yavuz Duvarci [a], Tan Yigitcanlar [b,*], Shoshi Mizokami [c]

[a] Department of City and Regional Planning, Izmir Institute of Technology, Gülbahce, Urla, Izmir, Turkey
[b] School of Civil Engineering and Built Environment, Queensland University of Technology, 2 George Street, Brisbane, QLD 4001, Australia
[c] Civil and Environmental Engineering, Kumamoto University, 2-39-1 Kurokami, 860-8555 Kumamoto, Japan

ARTICLE INFO

Article history:
Received 25 November 2014
Received in revised form 3 June 2015
Accepted 18 August 2015
Available online xxxx

Keywords:
Transportation disadvantaged
Social exclusion
Transportation disadvantage-impedance index
Policymaking
Simulation modelling
Arao, Japan

ABSTRACT

Access to transport systems and the connection to such systems provided to essential economic and social activities are critical to determine households' transportation disadvantage levels. In spite of the developments in better identifying transportation disadvantaged groups, the lack of effective policies resulted in the continuum of the issue as a significant problem. This paper undertakes a pilot case investigation as test bed for a new approach developed to reduce transportation policy shortcomings. The approach, 'disadvantage-impedance index', aims to ease transportation disadvantages by employing representative parameters to measure the differences between policy alternatives run in a simulation environment. Implemented in the Japanese town of Arao, the index uses trip-making behaviour and resident stated preference data. The results of the index reveal that even a slight improvement in accessibility and travel quality indicators makes a significant difference in easing disadvantages. The index, integrated into a four-step model, proves to be highly robust and useful in terms of quick diagnosis in capturing effective actions, and developing potentially efficient policies.

1. Introduction

The research conducted over the last decades resulted in identifying the major problems and locations of socially excluded (in broad terms, people with the lack of participation in the economic, political and social life of the community) and transportation disadvantaged (TDA) (in broad terms, people that are prevented from participation in the economic, political and social life of the community because of the reduced accessibility to opportunities, services and social networks) groups (Litman, 1997; Schlossberg, 2004; Duvarci and Yigitcanlar, 2007; Delbosc and Currie, 2011a; Blair et al., 2013; Kamruzzaman et al., 2015; Rashid and Yigitcanlar, 2015; Schwanen et al., 2015). As a result, many cities around the globe develop policies in order to meet the needs of these groups (Battellino, 2009). Utility of new technologies and high capacity computers are seen as support tools in these policymaking efforts (Yigitcanlar et al., 2010). However, estimating the effectiveness of policies beforehand is immensely critical, where this can be achieved by implementing cost-effective simulations using transportation models (Kamruzzaman and Hine, 2011; Kamruzzaman et al., 2014). Yet, up-to-date travel demand model software packages have neglected to incorporate social considerations and the required equity parameters, even for the neediest—i.e., disabled and elderly (Banister, 2002; Delbosc and Currie, 2011b; Lucas, 2012; Wasfi et al., 2012).

Furthermore, as emphasised by Lucas (2012, 112), "if properly designed and delivered, public transport can provide a part of [the TDA] solution, but it is most likely that other forms of more flexible (and often informal) transport services will be needed to complement these mainstream services. [Nonetheless,] this does not come cheap." Consequently, insufficient funds, high costs of special treatment of TDA, and costly provision of the special services enforce policymakers to look for cost-effective, timesaving, appropriate, and applicable solutions (Metz, 2003). Simulation models provide opportunity to test policy effectiveness before their implementation (Barceló, 2010); however, at present there are no straightforward policy simulation applications in the TDA domain.

The primary aim of this research is to develop an indexing approach, 'disadvantage-impedance index (DIX)', to fill this gap. Travel 'impedance' to the nearest service, in distance or time, is a commonly used measure of spatial accessibility (see McGrail and Humphreys, 2009). The term is also used to refer to transport related disadvantageous situations travellers experience such as very long walking distances to/from public transport stops or poor quality of public transport system (see Bunker et al., 2015). DIX is developed through the adjustment of modelling routine, as existing software are restricted in effective policymaking due to neglected social considerations. This indexing approach enables obtaining the best policy measures requiring only single-shot collected data in utilised cyclic run iterations. In DIX, stated

* Corresponding author.
E-mail addresses: yavuzduvarci@iyte.edu.tr (Y. Duvarci), tan.yigitcanlar@qut.edu.au (T. Yigitcanlar), smizo@gpo.kumamoto-u.ac.jp (S. Mizokami).

http://dx.doi.org/10.1016/j.jtrangeo.2015.08.014
0966-6923/

preference data technique (P.data) is used to obtain detailed information from the population, for better and quicker policy capturing, instead of blind trials for finding best policies. This approach aims to provide a solution to represent TDA views in policy determination. Therefore, it utilises mixed stated preference and revealed preference survey techniques, to understand traveller reactions against various policy scenarios, and helps inclusion of the user preferences, and thus enables participation of TDA in the policymaking process containing different scenarios and solution options (Lam and Xie, 2002; Alver and Mizokami, 2006; Duvarci and Mizokami, 2009). Investigating the compatibility of the approach to commercially available mainstream software—i.e., JICA-STRADA—is the secondary aim of this research.

2. Literature review

The common characteristics of disadvantaged populations are extensively discussed in the literature—see Church et al. (2000), Hine and Grieco (2003), Hine and Mitchell (2003), Duvarci and Yigitcanlar (2007), and Duvarci et al. (2011). While mostly used interchangeably, TDA and transport-related social exclusion are not necessarily synonymous with each other. For instance, a socially excluded can have good access to public transport options or a transport disadvantaged can be socially included (see Stanley and Vella-Brodrick, 2009; Delbosc and Currie, 2010). According to Lucas (2012, 106) “rather [TDA] and social disadvantage interact directly and indirectly to cause transport poverty. This in turn leads to inaccessibility to essential goods and services, as well as ‘lock-out’ from planning and decision-making processes, which can result in social exclusion outcomes and further social and transport inequalities will then ensue”. Not only personal and socioeconomic reasons (Licaj et al., 2012), but also the transport system itself can have a crucial role in creating barriers (Church et al., 2000). Hine and Grieco (2003) argue that combination of poor accessibility with low levels of mobility, and low levels of sociability intensifies the social exclusion. According to Lucas (2006) among the TDA categories, the elderly and disabled deserve more attention.

Many countries—i.e., Sweden, Canada, and Australia—have already launched legislations requiring improvements in transportation services such that all members of the society have equity in accessibility and mobility (Currie et al., 2009; Dodson et al., 2010; Engels and Liu, 2011; Jones, 2011). France, Spain, Canada, New Zealand, and South Africa are responding to the TDA agenda, and without directly calling it TDA policy, the USA, Germany and the Netherlands offer policies to address the transport needs of disadvantaged groups (Lucas, 2012). The success factors are among the most popular issues for effective policy solutions for TDA groups (Rau and Vega, 2012). Developing special infrastructure (e.g., technology equipped special services) for aiding TDA groups (especially disabled and elderly) is needed; however, it brings additional cost to local authorities, which is a major obstacle in implementation (Mokhtarian et al., 2006). Developing appropriate policies with support of technology is a much more cost-effective method in aiding those vulnerable groups (Nicolle and Peters, 1999; Duvarci and Mizokami, 2007; Yigitcanlar and Kamruzzaman, 2014), which requires detailed information such as travel demands, preferences, modes and paths of the population.

Gaining information about the TDA groups is necessary to identify and document their accessibility and mobility needs (Lucas, 2011; Power, 2012), which can be suitably acquired through four-step travel demand modelling. The importance of planning integrated to travel demand models has been ignored in the contemporary efforts due to unawareness and lack of coordination between social institutions, including health and transportation service authorities. Nevertheless, the ability to configure proper policy measures to help improve the TDA is of prime importance for policymakers to lessen the avoidable costs for both operators and users (Diana, 2004).

Measurement and level of analysis difficulties arise in TDA studies due to the multi-dimensionality of TDA. However, in some of the TDA studies (Duvarci and Yigitcanlar, 2007; Duvarci et al., 2011), these methodological issues were addressed by using P.data. This helped in determining the degree of disadvantages in social and geographical terms. There is a need for developing a clear methodological approach to determine appropriate policies to decrease disadvantages—making TDA people equal or close to non-TDA (NTDA) population in terms of their travel characteristics and opportunities. However, while providing solution to TDA problem, it carries the risk of increased demand on the road network causing congestion. Fortunately, a simulation study (Duvarci and Mizokami, 2007) reveals that even in the case of removal of all disadvantages, releasing suppressed trips of TDA would not cause a burden on existing road infrastructures.

3. The disadvantage-impedance indexing approach

The disadvantage-impedance Index (DIX) is developed with an aim to compare available policies to improve TDA's travel conditions and test effectiveness of these policies in a simulation environment. The structure and cycling process of the indexing approach are shown in Fig. 1. The data used in the index is clustered as TDA and NTDA. Information from P.data, fed by the current (*t* time) clustering results of TDA, guides the choice of appropriate policy areas to focus on. Convinced that improvements through simulations (both in terms of significantly easing the disadvantages and network congestion) are satisfactory to reduce the gap between TDA and NTDA, indicator index values are converted to composite index values (DIX) and should be treated for observing new cluster analysis ($t + 1$ time) results. This is to test whether the TDA population changed and the gap (cluster centre results) is further reduced. The process stops, if the goal is achieved, and the best solution scenario is nominated. Only the changing P.data values—along with TDA profile improvements at each cycle—are applied to the same modelling values.

The clustering process of the index is a dynamic one, and its results are expected to change (improvement for TDA) after each iteration cycle. Hence, the index always uses the same data in normalised index values for convenience of input–output cycle operability, and for reducing complexity. As stated by Parumog et al. (2008) using the improvement ratios as the common measurement between non-comparable indicators is a suitable technique for normalisation of values. In the light of the new TDA evaluation routine—using cluster analysis, P.data, input of DIX indicators—improvements in the travel demand modelling structure of a commercial transport modelling software (i.e., JICA-STRADA) are elaborated as below.

Improvements made through simulations in the original zonal DIX are achieved by: (i) Obtaining the improvement rates by zones and indicators, and; (ii) converting the improvements into averaged rate values by zones to be added to the respected indicator index values. The ratio change of TDA out of total population, as a result of the next clustering cycle, is a concern for evaluating performance of the system. This ratio change would not be a sole evaluator when the ratio of TDA can get even larger than the previous case, if its conditions are improved because of the increased numbers of TDA getting closer to NTDA. Thus, the metric gauge used for the improvement should be the reduced gap between overall cluster centre values of the two populations (increase in the TDA's cluster centre value) instead of the number of TDA people. Cluster centre values of each indicator for each zone can be used as a gauge to measure the improvement. If cluster centre values of TDA and NTDA converge to a negligible difference (5%), the process and the search for equalisation of TDA to NTDA should be stopped, and the finalised simulation results should be reviewed for policy analysis. The Pareto optimality condition is reserved such that any increase in DIX can only rise up to that of NTDA; if exceeded, imbalance of disadvantage would be borne, avoiding equity. The way to sort out the best policies within this mechanism is beyond the scope of this paper.