Transportation Planning and Technology
Vol. 32, No. 2, April 2009, 167–194

Routledge
Taylor & Francis Group

A suppressed demand analysis method of the transportation disadvantaged in policy making

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(Received 16 September 2007; final version received 2 March 2009)

This paper proposes a method for estimating transportation supply requirements when the suppressed demand of the transportation disadvantaged (TD) can be calculated and added to existing demand for travel. The underlying assumption is that the travel conditions of these TD groups must be equal to the 'conventional' demand, known as 'full release'. Utilising the modelling approach for TD, suppressed demand analysis, diagnosis of difficulties and equity between conventional and disadvantaged groups were realised, while elaborating special cases for the most vulnerable TD groups (such as elderly and disabled persons) and simultaneously identifying areas of difficulty. From the early virtual results, it is concluded that, for the full release of suppressed trips (only a 5% increase), policy makers must be ready to face some financial burdens, requiring coordination of effort to both standardise these TD groups and reduce the costs incurred by operators.

Keywords: suppressed travel demand; transportation disadvantage; disabled and elderly persons

Introduction

At present, there is continued growth in both the number of transportation disadvantaged (TD) persons and the various forms and aspects of disadvantage faced by them. This is primarily due to demographic trends (an increasing number of elderly users, as well as disabled and young users in developing countries), suburbanisation and a de-emphasis on coordination issues, still in their infancy. The essence of the problem is that elderly and disabled persons will require more assistance (Howe 1992, Lucas 2006). Hine and Mitchell's (2003) work summarises such efforts and points out policy directives for future coordination and planning efforts, while also presenting examples of prior applications that must be re-initiated. Many well-intended

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ISSN 0308-1060 print: ISSN 1029-0354 online

DOI: 10.1080/03081060902861400
http://www.informaworld.com

policies have been proposed, but in reality most have been hampered in implementation by funding and coordination difficulties. Meanwhile, continuing developments such as big retailers replacing smaller local shops, increased distances to major local activities, centralisation of health services and the removal of transit routes from low income districts are taking place at an ever increasing rate (Pennycook *et al.* 2001, Lucas 2006). In order to foster the coordination necessary for equity in accessibility, transportation and human services agencies need to collaborate during the planning process and take into account all these social aspects (Grieco 2003, Hine and Mitchell 2003). Successful transport policies must be sensitive to types of people affected and differentiate accordingly (Heggie and Jones 1978). This policy analysis can be fundamentally based upon identifying and separating out TD and non-disadvantaged individuals (or households). Despite the growing literature and interest in this issue upon the recent call for governmental policy on matters of social exclusion in the UK, and as identified in the 2004 Transport White Paper, there remain both methodological and conceptual struggles in tackling this issue in a comprehensive manner even in developed countries. Multidimensionality in the definition of TD prevails and complicates the frame of analysis for deriving travel patterns in addition to the inherent measurement difficulties.

While locating the issue to an extent and enriching the discussion, most studies have failed to define and address the issue of integrating suppressed demand comprehensively *into* the modelling, which is necessary for a knowledge-based analysis of policies. In previous studies by Duvarci and Yigitcanlar (2007), methodological issues of such integration were addressed to the extent that there is now at least a working model for TD travel demand. The model of integration proposed therein was developed in order to enable the formulation of policies sensitive to the needs of disadvantaged persons. The measurability of suppressed demand, and that of disadvantaged groups in particular, remained unaddressed *within* the context of that model and no clear method had been proposed to tackle this issue since there had been no clear yardstick defined to measure it. In the new model approach, the degree to which the disadvantages (the marks on the TD yardstick) can be defined in both social and geographical terms has been investigated; however, the levels of suppressed demand remain unexplored. Defining disadvantage levels for each stage of the model and obtaining assignment indicators is one thing, while defining the amount of suppressed demand (and the release if all disadvantages are removed) is another. Preceding the modelling steps, a clear review of travel demand types must be undertaken. As Pendyala and Bhat (2006) stated, one of the key considerations in determining the efficacy of a model is to examine the ability of the model to quantify *induced* or *suppressed travel demand.* Thus, the purpose of this paper is, first, to determine a method of calculation for quantifying suppressed demand, or in other words, a measurement technique for the inclusion of the TD population, or the socially excluded (SE) population, to introduce a degree of quantification throughout the modelling steps, and then, to find a measure of the impact from the hypothetical release of this suppressed demand as the traffic assignment results of these TD groups, especially those of the most vulnerable in this particular case. Full removal of all disadvantages for these TD groups means their being equated to the conventional population's travel characteristics. This 'completion' rule comprises the very backbone of the quantification method of the so-called 'suppressed demand difference' in this study.

In the previous study, results from modelling showed that the TD population produced an overall trip rate per person that was less than that of the conventional population: 1.65 to that of 1.73. The present study concludes that, if all the suppressed trips of TD were released, this number will have risen to 1.78. Therefore this study takes as it an assumption that showing fewer trips is a sign of demand suppression. The TD population was also overwhelmingly inclined to use public modes of travel, as was expected, and this is also assumed to be a sign of suppression. The reasons behind classifying these populations as TD, and why they produce fewer trips, are extensively discussed in studies by Church *et al.* (2000), Pennycook *et al.* (2001), Hine and Grieco (2003), Hine and Mitchell (2003) and Duvarci and Yigitcanlar (2007).

To maintain equity, the hypothetical traffic impacts of the increased (or released) trips of the 'once' TD were observed and the additional cost burdens on the local government providing transportation services as well as the required infrastructure were determined, using a 'what if?' approach based upon previous modelling results. The realised results are only on the basis of these increased productions, and remain hypothetical, but are still informative and have the potential to be used as a decision support mechanism by planners and traffic engineers. The simulation results tell us, first of all, that with the addition of the total release of the suppressed trips (an increase of 5%), no serious stress on existing road capacity appeared, with the qualification, however, of these results being very specific to the case city. Secondly, the results show that in the trip distribution stage, the focus zone pairs of policy, and thus, the critical paths that the particular groups under consideration (elderly and disabled persons) employ overwhelmingly could be identified with ease, along with the adjoining link-based results concerning what existing problems and costs (or congestion) these groups may encounter with the release impact. Analysts will be able to observe the special groups' positions and define what special transportation services and policies would be required in meeting this extra demand. Thus policy makers can find means to alleviate the disadvantages, while still following the Pareto optimality principle of not disturbing the present situation of the remaining users.

This methodology-driven study concerns only trip production and its run-down implications up to the assignment stage, addressing operability through a four-step model. The uncontaminated impact of trip production suppressed demand release is also observed. Two assumptions to be stressed here in the analytical framework are: (1) the Pareto optimality principle is applied, not interfering with the demands of other populations; and (2) the requirement that the demand characteristics of the conventional population be the ideal target for the TD population.

In the second section, the literature concerning the concepts of demand types in connection to the TD concept is briefly reviewed. In the third section, the basic structure of the model for TD from the previous study and its major findings are highlighted. In the fourth section, both the suppressed demand calculation method and the method of integrating this calculation into the modelling for simulations of the net impacts are covered. In the fifth section, the results from the simulation are analysed and evaluated as to their policy implications. Finally, the conclusions and areas for further study are considered.

A review of the literature on transportation disadvantage and suppressed demand

While related to the TD concept, that of the SE population is a much broader term implying people or households that are not simply poor but that have additionally lost the ability to both literally connect with many of the jobs, services and facilities that they need to fully participate in society. Accordingly, there are seven basic possible exclusion types: (a) physical; (b) geographical; (c) exclusion from facilities; (d) economic; (e) time-based exclusion; (f) fear-based exclusion; and (g) space-based exclusion (Church *et al.* 2000). The term SE is often used in place of TD in some literature but, in fact, their domains address related but separate issues (Figure 1). SE is a

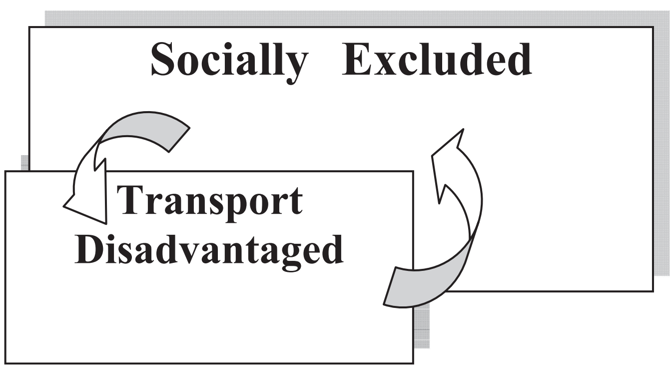

Figure 1. Cross impacting of social exclusion and transportation disadvantaged.

term referring in general to socio-economic wellbeing, with this relationship affecting TD, and vice versa, while TD refers simply to the disadvantageous conditions of transport, or accessibility. Accessibility and transportation are of vital importance in maintaining contact with the rest of society, and therefore, very closely linked to the concept of SE. Thus, the transport system itself has a role in creating barriers (Church *et al.* 2000, SEU 2003). Hine and Grieco (2003) argue that the combination of poor accessibility with low levels of mobility and low levels of sociability intensifies this exclusion.

Because of the multidimensionality (accessibility, mobility, cost, convenience and access to information) of TD, difficulties arise in measurement and levels of analysis. The present methods employed are far from being mature. A few disjointed studies have attempted to measure levels of exclusion. Research in the UK tended to adopt either a categorical approach or spatial approaches (Church *et al.* 2000) largely making use of GIS tools (PTAL or CAPITAL tools and ACCMAP, ABRA in those more advanced). However, these were found to be inefficient (Grieco 2003). Particular groups may not remain homogeneous throughout category analyses and other underlying non-physical factors (such as mode reliability or the time valuation of socio-demographic groups) may affect accessibility (Grieco 2003). Using the London Area Travel Survey done in 2001, the trip making characteristics of elderly and disabled persons for four trip purposes using an ordinal probit model technique were determined (Schmocker *et al.* 2005). According to these results, retired people can make trips in a similar fashion to those of the conventional population, but if disabilities intervene, overall trip rates drop dramatically.

Recently, a consensus was achieved concerning these disjointed efforts and requiring a comprehensive integration of these disadvantaged groups. The issue should be of concern to many related institutions and the following areas should be seen as priorities: the sustainability of accessible transport; better demand forecasting methods; and the needs of TD persons (Suen and Mitchell 2000). In addition to the awareness in the UK government, legislation in many other countries (including the USA, Sweden, Canada, Australia, etc.) require that transportation services be improved and made accessible to *all* members of the population, with routes more accessible to health services and shopping centres as well as housing, employing taxies with user-side subsidies, especially in assisting disabled persons, and pedestrian infrastructure and travel information for people with sensory, cognitive or linguistic impairments employing advanced technologies (Suen and Mitchell 2000). For example, it was found that low-floor buses increase the bus travel of TD groups (an *inducement* effect). Special infrastructure may be required in order to aid disabled and elderly groups, which may bring with it additional costs, and funding these will be the biggest obstacle for local authorities who may be unwilling to undertake heavy financial burdens. In order to relieve this funding obstacle, it is likely that the money charged to those who benefit most from the system will be specified for use in the improvement of public transport (PT), especially in emphasising the quality of service, and in improving service for those who benefit less at present, or suffer from a lack of service (Newman and Kenworthy 1999, Lucas 2006). There is currently a 'local transport planning' concept where equity between users is taken into consideration, and local participation is involved in more areas than simple efficiency and congestion concerns. The necessity for governmental assistance and *intervention* is strongly emphasised, with policies of active intervention needed to repair the areas of exclusion once the measurement problems in modelling are solved (Grieco 2003, Mokhtarian *et al.* 2006). With the increasing numbers of elderly and disabled populations, a gradual rise in the demand for demand responsive, door-to-door, ITS (Intelligent Transportation Systems) transportation services, and community transport alternatives in-between private and public modes are expected to replace private vehicles.

However, ascertaining the required amount of this additional infrastructure and its attendant costs depends, first of all, on determining the suppressed demand of those TD groups. Although some research literature exists on the measurability of induced demand using an elasticity approach as the ratio of the change in quantity of travel demanded over the change in travel supplied (Transtech Management Inc. and Bailly 2000, Cervero 2003a), less focus has been devoted to measuring the amount of suppressed demand and its impact. In particular, to what extent overall conditions should be improved remains an unknown issue. The elasticity technique can be also used for calculating suppressed demand. Empirical impact studies have been primarily confined to added lane miles on the amount and length of travel. Measuring the impact of induced or suppressed demand is also difficult due to the far reaching, complex and longer term impacts which are hard to calculate and where the impacting factors and those impacted should be clearly identified. The most easily forgone trips (suppressed trips) would be trips for social or leisure purposes, or some for maintenance, which are travel behaviours that are even harder to model. Most likely the suppressed demand of TD groups would be of this form, and those that they can most easily forego rather than obligatory trips, such as those for work, although their leisure activities and the number of trips are increasing (in the USA at least) (Mokhtarian *et al.* 2006). If the public transportation service level TD groups depend on is low, they are then more severely affected (Porter 2002, Lucas 2006). It has also been observed that TD groups comprise a majority of those 'peak captives' (Duvarci and Yigitcanlar 2007). As mentioned previously, this is partly due to the fact that they either defer social and leisure trips which are *less* important to them, or strictly plan trips at household level, combining them with these obligatory trips into a one-end vehicular trip. Family dependence in trip making is not only exhibited in the economic sense but also in the mobility sense, which is verified in the Srinavasan and Ferreira's (2002) study using large household survey data (1991) from Boston. Households without children tend to have fewer trips overall. The presence of children, residential location and employment seem to affect modal choices within a household. For elderly people living in suburban environments, there are no other alternative travel modes and they are forced to be 'mode captives' of the automobile after retiring (Davidse 2006). Elderly and disabled persons seem to be the most critical groups among the disadvantaged population with as much as 48% of those with disabilities and 53% of all elderly persons defined to be in the general category of TD (Duvarci and Gur 2003).

Travel demand types

Suppressed demand and induced demand are key subjects in the identification of the TD population and a heavy emphasis has been placed on measurements of disadvantages in the last decade, especially in the studies of Cervero (2003a,b), Mokhtarian and Salomon (2001) from the USA, and Litman (2005) providing a vast amount of empirical data for discussion. However, debates remain on specific definitions of demand types, primarily those of automobile traffic, which still have measurability and integration difficulties in modelling demand. Thus, there is an urgent need to understand travel patterns and the needs of the TD population and in parallel with this, the level of their suppressed demands in general.

The basic demand types are presented in correspondence with other types below and can be relevant in identifying inherent travel disadvantages, and the nature of TD travel:

- derived demand;
- generated and Induced demand;
- latent (referred to as 'real' demand); and
- suppressed demand (along with 'subverted' demands).

Wider definitions are provided by Litman (2005). Of these, the concepts related to suppressed demand will be discussed in depth in the next section.

Derived demand does not actually refer to a type of demand but to a state of analysis in demand modelling; from one extreme viewpoint, derived demand is the ideal demand, free from the existing demand in reality. From another viewpoint, according to that of descriptive modelling, the travel is 'derived' if it is not made for the purpose of travel itself but pursuant to other activities (Mokhtarian and Salomon 2001). The definition of generated demand is largely based on the assumption that the traffic exhibits behaviour analogous to that of a gas rather than that of a fluid – it tends to expand if the network capacity is increased simultaneously (Litman

2001). Thus for example, when new roads are opened, traffic fills them quickly, and the expected marginal utility of the new resource declines. On the other hand, induced demand is a sort of layer placed on top of generated demand. Through the changes made, more travel is attracted and the total volume of trips is also increased, usually as a factor of land use impacts (Litman 2001, Cervero 2003a). Thus, the total generated demand includes induced demand as a substantial part of its makeup.

New and longer trips quickly fill the increased capacity until the congestion equilibrium is re-established; however, pursuing this equilibrium in the real world would not be cost-effective (Downs 1992). For example, the huge suppressed demand for private cars in China does not seem satiable, and building the enormous infrastructure required to satiate this demand cannot be justified by any means (Zhang and Hu 2003). Cervero (2003a) criticises Hansen's famous finding that each additional 10% infrastructure spurs a 9% increase in traffic as 'overstated', because the increase must not be totally due to the induced impact but rather to the release of the *once suppressed demand* (or, the latent demand which was actually hidden and had not come to light until transport infrastructure conditions were improved, which he refers to as a 'causality' problem, and has yet to be well treated in demand estimation studies). He also relates the demand changes to the 'diverted' trips as induced trips. However, some studies distinguish between induced travel and diverted travel (Litman and Colman 2001, Noland and Lem 2002). Mode choice especially (as a diverted demand) is affected by the physical infrastructure available and the environmental characteristics such as the existence of sidewalks and the topography (Rodriguez and Joo 2004).

Suppressed demand of transportation disadvantaged (TD) groups and its relation to other demand types

Suppressed demand can be linked to the induced demand concept. If the assumption that induced demand is the contrary side of suppressed demand is accepted, then this must be valid especially for the TD population, whenever their travel conditions are improved. The suppressed demand of TD groups is only released where conditions such as accessibility and ease of mobility, lowered travel costs, etc. are improved. Those with lower levels of accessibility tend to plan and combine trips into one stop trips (Limanond and Niemeier 2004), which is also a form of demand suppression. But, some believe that induced demand is not simply a re-appearance of 'deferred' demand released at a later time, but that it is artificially created by traffic engineers and is beyond the impact of suppression (Newman and Kenworthy 1999). But, even if increased capacity and improved infrastructure make trips more attractive and cheaper, there must still be a ceiling point to the demand, and this is what is actually meant by the derived or desired demand. Suppressed demand can be alternatively defined as a form of oppression which is socio-spatially produced rather than naturally given. Thus, such disadvantaged individuals may tend to avoid travel if it becomes too troublesome in regards to the compared net utility gain from the outcome (accomplishing the activity at the destination) versus the disutility of making the trip, where quality of life depends to a large extent on ease of movement. For example, if an individual wishes to go work by bicycle but is unable to and must go by motor vehicle simply because there are not enough facilities for cycling, this means that their modal preference for the bicycle is suppressed. Thus, it is quite reasonable to think that suppression is primarily based upon the existence of adequate physical facilities in order for the latent demand to be fulfilled. Congestion may cause people to defer trips that are not urgent, choose alternative destinations or modes or even forego avoidable trips (Litman and Colman 2001). Many barriers were found limiting the social inclusion of excluded groups – limited travel choices (both spatially and temporally); excessive access distances to PT services and various problems encountered on route; the time required to reach destinations (as compared to going by car); poor service reliability (and thus, many trips cancelled or delayed); the limited availability of PT information in suitable formats; and the cost of using PT. However, the impacts and intensity of these barriers vary between population groups and the time of day. Similarly, improved environments (perceived safety, aesthetics of the road, etc.) and street design (traffic calming, rest facilities and slope), the quality and existence of bicycle facilities along major routes can all be cited as factors leading to an increase in bicycle trip rates. What was once suppressed demand can turn out to be realised demand, improving the level of equity, and thus, can help increase mobility with an increase in the level of personal satisfaction.

One dimension of suppressed demand, and interestingly also that of induced demand, is the number of 'diverted' trips that would be channelled to usually *undesired* modes, times and/or paths (that is why this type could be classified under suppressed demand). Another type is subverted demand, meaning that the trips were actually made but the activity that was the object of the trip was not accomplished because of late arrival or the absence of the activity due to a lack of information (Grieco 2003). Subverted trips can also likely be attributed to TD or SE groups. According to Grieco (2003), 1.4 million people missed appointments in one year in her UK study due to access difficulties. Subverted trips can be compensated for by more frequent, more direct and more reliable PT services.

From the literature review above, we can clearly see that the demand type of the TD population is a type of suppressed demand, since they are not provided with accessibility and transportation services to the extent that the conventional population is, and that this is due to personal or transport system based reasons, and the possible release of this suppressed demand could be interpreted as 'induced' in one sense, and as finding their 'derived demand' in another, as method of analyses if the purpose is to equate them to the conventional population, thus conforming to the aforementioned Pareto optimality rule. The basic relation set to induced demand is through inducement impact as travel increases or the diverted traffic of added infrastructure. Thus, considering a hypothetical scenario whereby means of some added capacity, technological support (such as ITS), special para-transit service and infrastructure, a sort of induced demand impact could be artificially conceived as those groups could then take trips as far as conventional people could and, thus, traffic impacts and other costs could be observed through this analytical framework. These types of observations are much more likely in a simulated environment based on the previous TRANUS model prepared for TD groups than could possibly be observed in reality. The results of such a simulation would be informative and useful as guidance in the policy-making stage. Also, measurability and an analytical framework can be devised through such a scenario approach.

It is also intended herein to introduce a new concept called 'suppressed demand difference' which is totally based on the unique cluster analysis methodology of TD modelling. In the next section, addressing methodology, we assume that the real (or latent) demand of the TD population is the ideal (or 'derived') demand, which is equal to the demand of the conventional population, and a measure is devised showing to what extent the suppressed demand of those TD groups could be released, a previous unknown. In simple arithmetical terms, this idea can be stated symbolically as:

$$R_{TD} = D_N - D_{TD} \tag{1}$$

where, $\mathrm{R_{TD}}$ (later denoted as Dij(rel) for the calculation of trip numbers in Eq. (5)) is the demand difference to be released for the TD (Transport Disadvantage) population, DN is the existing demand of the conventional population but here assumed to be the actual latent demand of TD, and $\mathrm{D_{TD}}$ is the existing (suppressed) demand of the TD. If the transportation conditions and accessibility of TD are restored, the released demand of TD becomes a sort of 'induced' demand of the TD due to the improvement impact.

Description of the modelling approach adopted for transportation disadvantaged (TD)

Case city and data: Aydin

Together with the usual transport network data included in the 2000 Census for Turkey, a household survey was conducted of 326 randomly selected households and interviews with a total of 932 persons. The sampling ratio of this survey was 0.7 per cent. Questions related to individual household members aimed to determine individual travel patterns in order to reveal disadvantage-related information (Duvarci and Yigitcanlar 2007). The model was tested in the city of Aydin, which is near Izmir, and had a population of 135,365 in 2000 with a compact settlement form. Wealthier groups reside in the areas surrounding the city centre, with the urban fringe mainly home to low income groups in contrast to the situation in most Western cities.

Brief findings from the previous model

The structure of the model that this study is based upon consisted of two basic stages after processing the data: (a) determining the disadvantaged population through cluster analysis and; (b) modelling the disadvantaged and conventional populations and comparing the results. A brief summary of the data variables used in the definition of TD are shown in Table 1 (the details of which can be examined in the respective study). These are based largely on attitudinal and perception data from the individuals surveyed in

Table 1. Data variables used in the modelling for the TD.

Category	Category name	Notes
ACCESS	Accessibility	Determine the number people with poor accessibility level to the basic urban amenities
DEPEND	Economic dependency	Measure the economic dependency of the family members
EDU.FAM	Education level	Indicates household level education status that reflects individual travel generation
INC.PER	Income level	Income per person
IMPED.MP	Mode and peak impediment	Represents combined effect of mode and peak captivity together with the emphasis on the disabled
IMPED.PT	Public transit impediment	Indicates public transit conditions (i.e. physical conditions of the bus stops, service frequencies, number of transfers)
IMPED.CU	Cumulative impediment	Represents the cumulative effect of basic impedance elements (i.e. travel time, cost and distance to stop or car park)
COM.PUB	Comfort level of public transit	Measures passenger density and comfort conditions of the public transit
SCH.TRIP	Journey to school	Indicates travel conditions of students with various measures
VEH.AVA	Motor vehicle availability	Determines the number people with no motor vehicle
COM.VEH	Comfort level of private motor vehicle	Private motor vehicle comfort level (i.e. odour, air condition, noise, cleanness, seat comfort)

combined index values that can later be easily used as parameters, or as policy intervention domains. In addition, other more usual parameters are used solely in the modelling steps such as figuring travel costs. Eleven major disadvantages (variables) were identified which constituted the criteria used in the clustering process to split the sample population into the two groups. The individuals with relatively low scores were placed in the disadvantaged, and the ones with high scores to the advantaged clusters. Consequently, the number of the disadvantaged was 629 and the advantaged was 303. The modelling approach required the separation of model runs of these two data sets.

Cluster centre results point to the fact that disadvantages are largely due to a lack of access to motor vehicles and to poverty. This analysis also demonstrated that it was possible to determine zone clusters of disadvantage through cluster analysis (Figure 2). Apparently, the most disadvantaged zone is the eighth zone, which also has very low socio-economic status data (Duvarci and Yigitcanlar 2007).

TRANUS™, integrated land use and transport modelling software, was employed in the modelling of transport for Aydin. As for PT, only one mode was available in the pilot study area, a contracted-out bus service that runs on 14 routes. For trip generation, the best fitting variables were educational level, income level and household economic dependency for the conventional population, using multiple regression analysis. For the disadvantaged, the following variables were significant: vehicle comfort, comfort level of PT and economic dependency (this being a common variable for both). The R^2 value was as high as 0.78. The highest R^2 value obtained for the disadvantaged was 0.69. The overall average daily trip rate per person for the conventional population was 1.73, compared to 1.65 for the disadvantaged. Trip production results by zone for both disadvantaged and non-disadvantaged groups are displayed in Table 2.

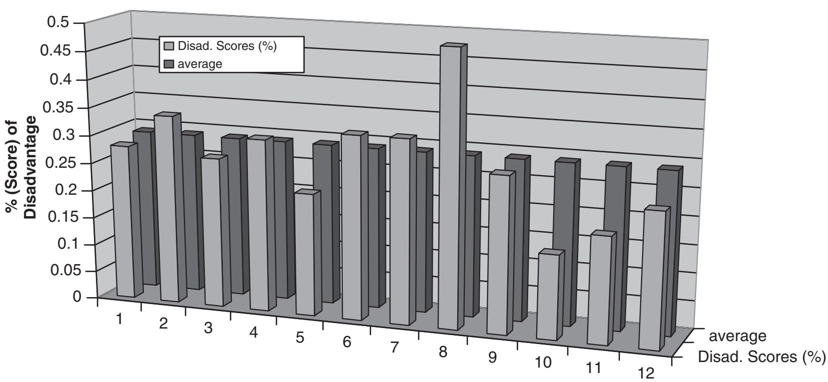

Figure 2. Aggregate disadvantage levels by zones (Duvarci and Gur 2003).

Table 2. Trip rates and productions of conventional and disadvantaged groups.

	Conventional population					Disadvantaged population		
Zones	Model trip rate	Survey trip rate	Population	Trip production	Model trip rate	Survey trip rate	Population	Trip production
1	1.81	1.88	12,261	23,075	1.72	1.93	7802	15,042
2	1.75	1.51	11,378	17,147	1.77	1.59	9510	15,111
3	1.87	1.61	9107	14,626	1.14	1.17	5657	6624
4	1.94	1.94	10,136	19,694	1.95	1.88	7659	14,437
5	1.88	1.94	13,477	26,132	1.99	2.3	7067	16,268
6	1.74	1.89	15,359	29,090	1.71	1.49	11,384	16,985
7	2.02	2.08	11,938	24,807	2.02	1.9	8661	16,499
8	1.23	1.33	13,046	17,312	1.24	1.31	12,042	15,799
9	1.54	1.4	9251	12,924	1.48	1.3	5829	7601
10	2.12	2.15	9683	20,828	1.73	1.94	3289	6394
11	1.4	1.28	9899	12,710	1.64	1.39	5377	7452
12	1.51	1.61	9830	15,816	1.4	1.51	5990	9063
Total	1.72	1.73	135,365	234,162	1.64	1.65	90,267	147,275

For the trip distribution stage, a singly constrained (production) gravity model was used to determine the distribution (for a more detailed explanation, see Duvarci and Yigitcanlar 2007). For the mode split stage, employing a binomial utility approach, the utility function for the disadvantaged could be explained solely by the combined impediment variable. The mode split preferences in favour of PT were 0.43 for the disadvantaged and 0.37 for the conventional population. To ascertain the final traffic results and performance determining indicator results for user disutility levels, the assignments were run using TRANUS.

Method of accounting for the suppressed demand of transportation disadvantaged (TD)

Observing the pure impacts of the 'once-suppressed' but now released demand (trip rate increase only) can be handled in two basic steps: first, calculating the demand surplus (difference) released by the TD and; second, integrating this released demand to the mainstream model structure and observing the impacts as the result of this assignment.

Method of calculating 'suppressed demand difference'

It is no easy task to measure a hidden fact, not simply because of its not being apparent, but also due to the uncertainties in definition and delimitation of what is to be measured. This difficulty in handling suppressed demand in four-step modelling has been stated because of the differences between the conditions for drawing up general trip making behaviour based on socio-economic conditions (the derived, or ideal demand) and the actual demand in actual trip making situations (the apparent demand) (Kitamura 1996). As mentioned earlier, the measurement process requires a 'yardstick' with which these measurements are to be taken. Here, the calculation method will be different from the aforementioned elasticity measurements as simply put in Eq. (1). Since the sum of the disadvantaged and the advantaged together make up normality, the suppressed demand of the TD can be found on the basis of this 'completion' assumption; suppressed demand is the 'deviance' of the disadvantaged from the normality in the existing situation by all means. Simply put, the subject of this paper is to explore what impact this extra generated demand would create on the existing transportation network and infrastructure. In the following, the released 'suppressed demand difference' for Aydin city is similar to the simple method as in the example shown above.

Method of integrating suppressed demand into modelling to find model outputs

The study is limited to the impacts of observable trip rate increases, that is, to the additional released suppressed demand of the disadvantaged. Since the previous modelling study used the singly constrained (O_i) trip distribution approach, only trip production will be introduced in the trip distribution modelling, and their impacts to the assignment stage, specifying no other value throughout the model stages, in order to carry out a pure impact analysis of the increased trips. The integration process can be explained in four basic steps based upon the previous modelling steps to obtain the disadvantage population, its trip production and trip rates.

Calculating 'Released' production of the disadvantaged ($O_i^{dis}(rel)$)

Multiply the population (P_i^{dis} for each zone) of the disadvantaged by the conventional populations' trip production rates:

$$\boldsymbol{O}_i^{dis}(rel) = P_i^{dis}.t_i^{norm} \tag{2}$$

Calculating released trip distributions of the transportation disadvantaged (TD) ($T_{ij}^{dis}(rel)$)

Previous attraction factors of the conventional population's trip distribution calibration is directly multiplied by the above result (Step 1) for released production ($\boldsymbol{O}_i^{dis}(rel)$) (as if future production):

$$\boldsymbol{T}_{ij}^{dis}(rel) = \boldsymbol{O}_i^{dis}(rel).\boldsymbol{a}_{ij}^{norm} \tag{3}$$

where, $\boldsymbol{a}_{ij}^{norm} = \boldsymbol{d}_j.\boldsymbol{f}(\boldsymbol{c}_{ij})/\Sigma_j \boldsymbol{d}_j.\boldsymbol{f}(\boldsymbol{c}_{ij})$, which is calibrated for the conventional population. $\boldsymbol{d}_j$ here means the total attractions by jth zones.

The reason for taking the conventional population's calibrated attraction factors, instead of the disadvantaged, is that the conventional values are always the ideal target for TD. The previously defined conventional parameter values are assumed constant for the new modelling with the released suppressed demands.

Running of all model steps on TRANUS (or other available software) as the two separate models, and finally getting the no-release assignment results (T(base)ijkl and the released demand assignment results T(rel)ijkl) for comparison

This requires, first, a run of the base year model, and then, a run of the suppressed demand's released trips, without changing any other parameter in the models.

Running the reporting programmes of TRANUS for the analysis of the assignment results, the performance indicators, such as disutility, cost and service levels

General indicator outputs are derived from the Reporting Programmes (IMPTRA and MATESP) to compare the basic results of the two models, checking the appearance of additional volumes, costs, vehicle demand, worsened level of service (LOS) conditions and disutilities. The results can be controlled either from the display results from the TRANUS Assignments Tabs, or from the numeric results from the reporting programmes.

Costs incurring to the operator (or local government) are of special concern here. The results are discussed in the next section covering policy implications. Finally, the meaning of these results for special TD groups, such as elderly and disabled persons, *falling under* the disadvantaged category can be analysed at one's convenience. Through this analysis, the following issues can be addressed: (a) the costs or additional burden (or facilities) of TD released suppressed demand; (b) what costs and difficulties TD groups may encounter as a result of the increased traffic; and (c) what infrastructure improvement and facilities are required according to the needs of the TD population. The process can be shown briefly as steps in chart (Figure 3). In this chart, the released Demand Integration of Special TD Groups (DSG) (to be explained later) is also shown.

Simulation results and comparison with the base 'no-release' case

To obtain the impact of released suppressed demand, simulation results of the released trips as of assignment results derived from the base model of the

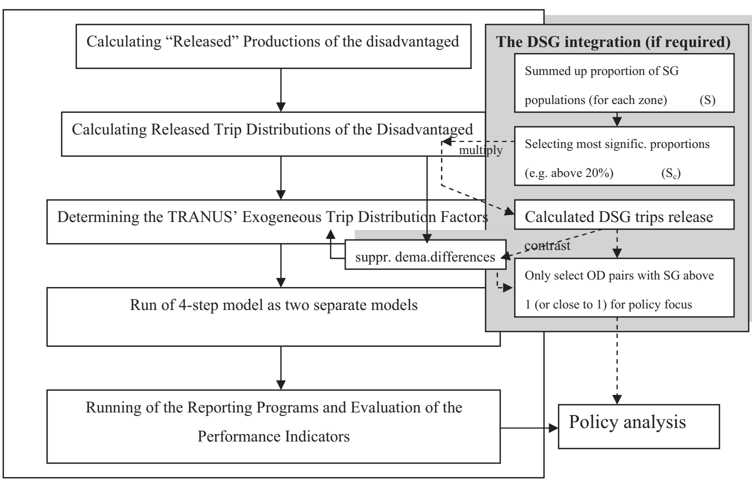

Figure 3. Steps of released demand calculation together with the JDED integration.

'no-release' case were evaluated on the TRANUS software. Both display results and general (summary) performance indicators for the 'release' and 'no-release' (base) cases were contrasted. The total suppressed trip release of the disadvantaged from the previous section was 154,009 including intra-zonal trips, this number was previously 147,123, which meant only an approximately 5% increase from the suppressed situation before release occurs. However, since the intra-zonal trips were not accounted for in the previous modelling, these numbers became 103,930 and 101,317, respectively, which is a trivial increase of about 3% (Table 4). There are also the constant external trips added to the base-year trips that pass through five external zones, which stay constant in all calculations in both the base and the 'release' case. Finally, the net released trips were obtained by subtracting the number of released trips with from the number of base year (or, 'no-release' case) trips (see Table 4). As shown in Table 3, we were not interested in the negative sign results and, thus, they stayed out of our concerns, which are marked by parentheses, meaning that literally no released trips occurred. The most significant releases are the bold and underlined ones. These are to function as the policy concern zone pairs. Only the bold ones are determined to be significant. The net release (difference) can be denoted as:

$$D_{ij(rel)} = \boldsymbol{T}_{ij}^{dis}(rel) - \boldsymbol{T}_{ij}^{dis}(base) \tag{4}$$

Finally, the results from the simulation and base-year results were compared, and the basic differences between the two were evaluated across three basic display indicators (from top to bottom: public and private mode equivalent vehicles, the LOS and wait times, all with the same scaling) that showed literally no significant difference between the base 'release' and 'no-release' cases (because of the present available capacity to accommodate an increase traffic in the case of Aydin). There were only a few slight differences in the LOS as released trips heightened congestion levels a bit, especially on previously congested links (Figure 4).

Similarly, utilising the IMPTRA reporting programme of TRANUS, numerical results for basic costs, disutility and mobility related indicators could be obtained. The general results achieved, according to the simulations, are summarised in Table 4 and compared to the base-year results. From these results, it can be generalised that the new case (release of demand) imposes slightly higher cost burdens on both private and public modes but, at the same time brings higher revenues, too. A detailed explanation of these findings is provided in the discussion section.

As mentioned earlier, results peculiar to special demand groups (SDG) such as the elderly and disabled, and their required transport needs, policies and the necessary investments could also be captured and approximated by simply adjoining the population ratios into the trip distribution stage (see Figure 3), which have been already addressed elsewhere (Duvarci and

Table 3. Differences between the base and released trip distributions of the TD.

	1	2	3	4	5	6	7	8	9	10	11	12	Sum
1		1053–1873 **820**	5265–4058 (1207)[a]	2633–3121 **489**	527–312 (214)	3159–2653 (506)	97–47 (50)	97–47 (50)	527–312 (214)	790–312 (478)	263–312 49	97–312 215	14,507–13,360
2	556–412 (144)		556–421 (135)	2223–2104 (120)	1112–1262 150	556–1262 **706**	556–841 286	102–64 (39)	1112–1262 150	1112–841 (270)	1946–1683 (263)	1946–1683 (263)	11,776–11,836
3	54–29 (25)	879–774 (105)		1554–1026 (528)	54–387 333	54–581 **527**	586–581 (6)	54–194 140	293–387 94	54–194 140	54–348 294	54–736 **682**	3691–5236
4	97–51 (46)	1053–706 (348)	1211–1518 (306)		527–1059 **532**	1580–1059 (521)	790–1059 269	97–53 (44)	685–1518 **833**	158–106 (52)	527–459 (68)	2265–2224 (41)	8991–9811
5	1453–756 (697)	484–264 (221)	89–264 174	2421–2108 (313)		1937–1581 (356)	2421–1318 (1103)	89–40 (49)	968–1054 86	89–264 174	1211–922 (288)	2179–1713 (466)	13,342–10,284
6	494–433 (61)	91–629 **538**	988–839 (149)	3460–3776 316	988–1259 270		988–839 (149)	91–63 (28)	494–1259 **764**	494–420 (75)	1236–1175 (61)	1730–2014 284	11,055–12,705
7	56–252 196	56–489 **433**	303–367 63	3640–3423 (217)	910–1467 **557**	1759–1711 (48)		56–37 (19)	303–244 (59)	303–489 186	1972–2078 108	2427–2567 141	11,785–13,125
8	328–46 (282)	60–45 (16)	328–591 263	656–1182 **526**	656–591 (65)	525–473 (52)	984–886 (97)		754–680 (75)	656–591 (65)	984–886 (97)	656–591 (65)	6586–6561
9	63–37 (26)	343–228 (115)	686–1141 **455**	343–1141 **798**	63–34 (29)	63–34 (29)	686–456 (230)	63–34 (29)		686–456 (230)	63–228 165	63–34 (29)	3124–3826
10	99–32 (66)	99–218 119	535–1090 **554**	535–763 227	535–436 (100)	535–33 (502)	99–436 337	99–33 (66)	99–436 337		803–654 (149)	803–981 177	4241–5110
11	66–25 (42)	359–172 (187)	66–1031 **965**	1796–1598 (198)	1078–1031 (47)	66–172 106	66–172 106	359–172 (187)	359–172 (187)	359–172 (187)		898–1083 185	5474–5800
12	420–227 (193)	420–241 (180)	77–481 **404**	1261–1203 (58)	420–481 61	1261–722 (539)	77–481 **404**	77–36 (41)	840–722 (119)	210–120 (90)	1681–1563 (117)		6745–6277
d_j	4213	8234	13,038	25,947	9775	17,426	12,053	10,367	10,895	7053	12,714	15,428	**10,1317**

[a]The values in parentheses are negative sign values meaning that the actual demand is already greater than the released (supposed to be more) demand. Thus, they are not concerned due to the non-erratic behaviour in this study.
Note: External trips are not added to these figures.

Mizokami 2007). A summary of results showing the most significant shares (close to one or over; here those over 0.8 were highlighted) is presented in Table 5, where those in bold and underlined are the most significant ones, while the grey-toned ones are under the proportionate value 1, but *still* showing potential significance, and the others not having the critical number of trips necessary for evaluation. Here, those that are most significant are selected. Simply put, these 'special demand' traffic releases of significant ratios (those having larger shares) to other zones can be observed on the network paths, and also whether these groups encounter any impediment caused by the additions of the general suppressed demand releases of those TD groups, such as the increased volumes, generalised costs, LOS and length of wait time for PT services. Evaluations of these factors for significant zone pairs, as well as related paths, are covered in the following section.

Discussion and policy implications

As a general outcome of this methodological approach, the total trip demand of the TD, which was 147,123, increased to 154,009 trips, and these extra 6886 trips can be seen as the latent or derived demand, which came about as a result of the aforementioned hypothetical release of the suppressed demand. If this gain is added to the total number of trips undertaken by the conventional population (6886 + 234,244 = 241,130), and divided by the total population (134,265), a new trip rate of 1.78 is obtained, which is 0.05 higher than the previous value. A slight increase in trip numbers has not actually brought about much more of burden on existing

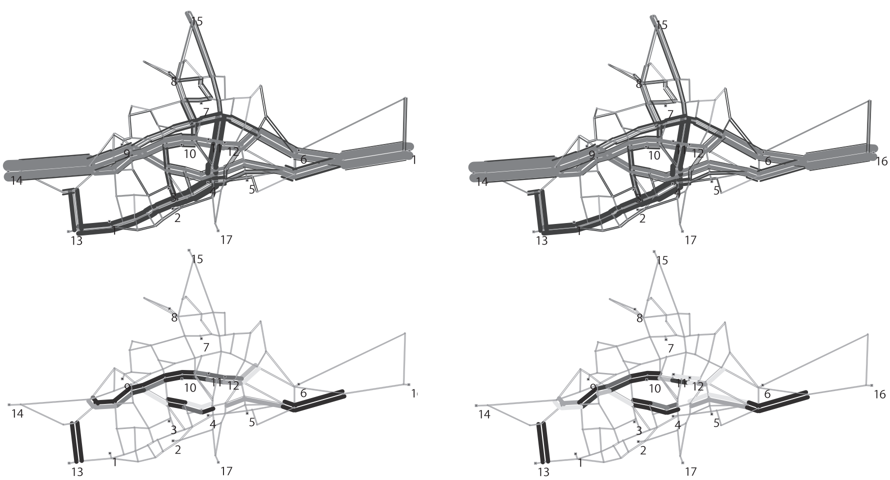

Figure 4. Comparison of simulation (left side: release) and the base year (right side: no-release) assignments display results.

Table 4. Comparison of the base case and the simulation of released demand.

	Criteria	Base case (no-release)	Simulation (released suppressed)	Percentage (%) change
Modal cost and benefit	General costs (private)	14,593,131	14,829,517	1.61
	General costs (public)	**11,506,755**	**11,759,606**	2.19
	Revenue (private)	4,865,501	5,017,459	3.12
	Revenue (public)	**19,590,252**	**20,014,686**	2.16
	veh/km (mobility, private)	112,991	115,951	2.62
	veh/km(mobility, public)	59,968	61,592	2.71
Costs	Monetary cost (generation)	**51,293,628**	**52,343,596**	2.05
	Passenger travel time	59,804	71,158	18.98
	Passenger wait time	4,62 (+E18)	4,37 (+E18)	−5.41
Distances	Passenger distance (private)	225,983	231,903	2.62
	Passenger distance (public)	820,284	837,365	2.08
	Passenger distance (pedestrian)	147,589	144,455	−2.12
Users costs (per capita and total values)	Distance (average)	1.61	1.68	4.35
	(total values)	162,063	177,054	9.25
	Cost (average)	39.68	42.91	8.14
	(total values)	4,000,035	4,515,849	12.89
	Travel time (average)	0.22	0.20	−9.09
	(total values)	21,931	20,623	−5.96

Table 4 (*Continued*)

	Criteria	Base case (no-release)	Simulation (released suppressed)	Percentage (%) change
	Waiting time (average)	8.22	7.5	−8.76
	(total values)	8,292 (+13E)	7,87 (+13E)	−5.09
	Disutility (average)	356,217	294,127	−17.43
	(total values)	3, 59 (+10E)	3,1 (+10E)	−13.65
Modal trip changes	Private trips (disadvantage)	1171	1196	2.13
	(total)	50,235	51,318	2.16
	Public trips (disadvantage)	99,641	104,046	4.42
	(total)	297,888	301,234	1.12
	Total trips (disadvantage)	100,812	105,242	4.39
	(total)	348,123	352,553	1.27

Note: bold values show the important areas of interest directly related to the situation of those disabled and elderly.

Table 5. The proportion of released demand of elderly and disabled (DED) to the released suppressed demand difference of the TD (for significant groups only).

	1	2	3	4	5	6	7	8	9	10	11	12
1		**0.32**		**0.89**								
2					**2.60**	**0.55**	0.91		**2.60**			
3						**0.43**						**0.42**
4			**2.13**		**0.86**		**1.69**		**0.78**			
5												
6				**2.98**	**1.16**				**0.41**			**1.77**
7					**0.58**					0.58	**4.29**	**4.02**
8			**1.12**	**1.12**								
9			**0.50**	**0.29**								
10			**0.51**									**1.44**
11												
12												

roadway capacities, and so is not deemed a serious burden on local government, as this is only 3% with the exclusion of the intra-zonal trips (most of which are expected to be non-vehicular). That is to say, almost 40% of the suppressed trips remain close to home. Even much of the inter-zonal released demand still remains in the close vicinity of the home. These conclusions bring back to mind the importance of walkways and related street infrastructure in the removal of suppressed demand. Ironically, these additional trips might not always mean additional costs and burdens to the existing infrastructure but, instead, returns to the system in these cases where the existing network and transport system capacity is underutilised, which is another facet of cost. For example, revenues slightly higher than costs were also observed (if no discount for the TD population was assumed) in those cases where some increases in operational costs appeared. Thus, the evaluation of questions concerning additional costs or benefits brought about by the release of suppressed demand requires careful interpretation and is case sensitive.

Once the critical traffic paths to be emphasised are clearly determined, the next step is to entail these policy variables for possible scenarios in policy making.

According to the special results for the elderly and disabled that arose in the simulation, in examining the impacts by paths (one direction) on the Paths property of TRANUS, summary observations of critical OD (Origin-Destination) pairs, only those with a demand of elderly and disabled (DED) ratio above two, are listed here: (2–5), (2–9), (4–3), (6–4), (7–11) and (7–12). The zone pair (6–5) with a DED (Demand of Elderly and Disabled) ratio of 1.16 is also examined for its unique quality as shown in Figure 5. TRANUS produces several possible alternative paths for all modes based on the shortest path rule from that of the least generalised cost to that of the most. The general impedance characteristics of these zone pairs were, primarily, that they usually have walk modes proposed by TRANUS as the best choice paths (the first two or three alternatives). This was primarily due to these paths having extremely long and indirect transit lines which seemed to be an impediment that was unable to be overcome. Even while the proposal of these walk modes can be interpreted as a positive development, the distance between the zones may not allow for this option, especially for the elderly and disabled. Secondly, of the various PT choices available at the beginning of trip, the majority of these are reduced to a choice of only one or two options, and there may not be any direct routes to and from the destination zone. Moreover, even in those cases where many PT alternatives exist, the distance to either access points or egress points is often rather far. Thirdly, many trips are interrupted by a lower LOS on some of their links (this may have deteriorated slightly due to the impact of these released trips but had been prevalent on some of the major through-traffic links previously, and therefore, it may be better to re-design these transit service routes, or develop other solutions to deal with the overflow), or delayed by long wait times, which may be due to infrequent or unreliable bus services. In those cases where such impediments occur, policy makers should employ case sensitive, relevant policies to help improve the quality of service available to elderly and disabled persons, adopting methods such as on-call paratransit services equipped with the necessary technology and other infrastructure directed towards their particular needs. In Figure 5, which shows a common attribute in the simulation results, one of the most important factors causing a disadvantaged situation was seen to be the extreme indirectness of the existing lines of PT, and in these cases the path choice of a walk mode (even

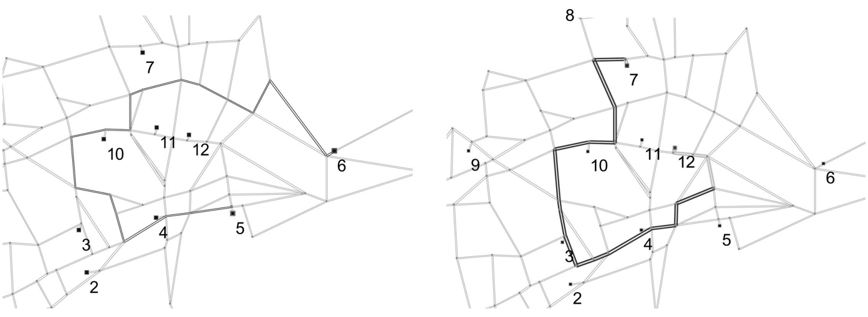

Figure 5. Path examples (6–5 and 7–12) of extremely indirect PT routes as major impedance.

where the zone pairs were not so close to each other) becomes more beneficial in terms of the generalised cost on the critical paths selected.

An evaluation of the data in Table 4 is required even though the results do not tell us much about the differences between the base (no-release) case and that of the simulated release. However, the results indicate the general results of the entire city, not only those of the TD population. Looking at the costs and benefits for operators, there are around 2–3% increases with the observed increase of 5% in the general trip rate, so one can say that costs and revenues (assuming ticket prices are not discounted for the TD groups) almost even out. It is interesting to note, however, that there is an almost 5.4% decline in overall wait times, which is a positive indicator. Looking at per user (average) results, although there is a fair increase in the amount of distance travelled (4.3%) and the costs (8.1%) per person, there are even more dramatic decreases in the wait time at bus stops (8.8%) (due most probably to the increased frequency of service), disutility (17.4%) and travel time (9.1%), and these results are beyond what was to be expected. In the criteria for modal trip changes, there is a slight increase in the number of private trips (2.15) by the disadvantaged, which can be interpreted as an improvement in their mobility. Of even more benefit is the greater inclination of the disadvantaged to use PT modes, most likely because of the improved conditions in PT, and this allows for transportation policies which focus on improvements of PT conditions, since it promises greater benefits for disabled persons.

Accordingly, issues of what can be carried out in practice and how these results can be utilised are those of the policy making and planning process, taking into account coordination issues. Although these issues are beyond the scope of this paper, there is a necessity to connect the outcomes of this research to these policy making and coordination efforts. First of all, in compliance with new legislation that has been proposed in many countries, the use of advanced technology show great promise in aiding those vulnerable groups, such as the elderly and the disabled, after the level of their demand and the paths they will use are known. Planners must become aware of the fact that only if appropriate policies are applied and improvements, primarily technological aids and facility improvements, are undertaken for the purpose of providing the TD with service, will disadvantaged groups release their real travel demands. This is therefore a method of returning the deferred transportation service utility back to them. Many on-going UK-based projects as PEDFLOW (Design of Pedestrian Networks and Facilities especially modelling vehicle/pedestrian interaction), PERMEATE (Pedestrian Activity Measurement in the Transport Environment) and studies exploring the role of transportation in social exclusion, and projects such as TELSCAN (TELematic Standards and Coordination of Advanced Telematics systems in relation to elderly and disabled travellers), a detailed study aimed at developing a design guidebook for

ITS designers, all show some promise in helping to improve present travel conditions, especially those of the elderly and the handicapped. In the improvement of trips for the disadvantaged and the release of suppressed demand, the possible role of ICTs has been shown to be of great worth (Church *et al.* 2000).

Information is the second essential parameter on the way to improving travel conditions, especially for those who have hearing, visual or other sensual impairments as well as for conventional travellers, which is an issue that can also be solved with ITS, and while it was not a major issue among our sample of PT users, it would seem – as Grieco (2003) has put it – that those who are dependent on a service tend to know their way around it in some detail. But the use of some forms of ITS technology, while offering means of 'virtual mobility' to assist TD groups in accomplishing activities without actually travelling, does not appear to be a satisfactory solution, as this could lead to more isolated individuals, and more suppression of real (latent) travel demand under the guise of this 'virtual mobility', even in those cases where the activities are accomplished, this conflicts with the very idea of helping the disadvantaged to release their suppressed demand. Above all, coordination efforts and the role of active participation for effective feedback mechanisms concerning applications is a necessity that local authorities must encourage. As Grieco (2003) puts it, unless the direct participation of the SE is built into the design of transport research and transport operations, the consequences of poor system design remain borne by the excluded and will continue to go largely unvoiced.

Funding issues are another point that needs to be resolved urgently for these costly ITS-based applications, but these are, in a sense, a form of compensation which helps return to the TD groups their deferred rights both in terms of the effective utilisation of transport facilities and the restoration of full accessibility. Local governments should be prepared to have available funds and new organisational structures ready to accomplish this task of restoration, while not requiring as large a share of budget as previously hypothesised (Grieco 2003).

In practice, efforts aimed at reducing travel by private vehicle, employing non-monetary measures such restrictive car parking (thereby penalising the use of automobiles), priorities in enabling PT (greater frequency or alternative modes and more coverage in urban areas) and pedestrianism have been proposed as a means of overcoming the present inequities. Pricing and other monetary measures focused on motorists and used as a means of compensation favouring disadvantaged groups are suggested as strong tools. These funds can then be directed to the improvement of the TD population's travel conditions. There can be many policy measures of both supply and demand types, and among these of special interest are: (1) additional transit services with particular characteristics and improvements in services; and/or (2) on-call paratransit service operators with flexible routes and discounted ticket prices for elderly, disabled and low income riders, which are heavily utilised by the elderly and the disabled. These propositions may be rather general but are presented as examples for possible future action. In previous modelling studies carried out by Duvarci and Gur (2003), similar scenarios showed good results in simulations, especially for those areas densely populated by the elderly, disabled and poor. In these areas paratransit services attracted most of the existing transit rideshare (as much as 90%).

Conclusion

Measuring suppressed demand has, in general, been a neglected subject. Over and above the small number of elasticity approaches, other techniques are required to take into consideration matters of transportation equity and the particular circumstances of TD groups. Measuring the impacts brought about by the hypothetical release of suppressed demand, and specifically of that of the TD population, through a simulation-based approach was the subject of this study.

Under this assumption, a cluster-based modelling approach for TD groups shows great promise in use as a yardstick for measuring the suppressed travel demands of these groups. Using the previous results of modelling done by Duvarci and Yigitcanlar (2007), a metric was developed based on a 'what if?' approach in the measurement of both the suppressed demand and the would-be impacts if that demand was released. The main purpose of this was to answer the question of whether the impacts and costs of such additional trips are heavier than the local government's and the existing infrastructure's capacity to handle them. In actuality, as was observed in the 'release' case scenario simulation run on TRANUS software, there was none of the expected heavy burden on the system. Secondly, the aim was also to identify, using the example of elderly and disabled groups, problems that can be diagnosed on the basis of a demand analysis of these special TD groups – the paths that will see heavy use (with the released trips), the attendant infrastructure needs on these paths and whether or not the impediments they encounter can be overcome. Thus, transportation authorities can make use of these results and deploy the appropriate policies, infrastructure designs and technologies in the right places in order to help to alleviate both general disadvantages and the particular disadvantages of the TD population, without worsening the present situation of conventional groups through added costs and congestion. The methodology proposed has worked successfully, and is in compliance with the previous modelling approach, producing results that can give guidance for evaluation in the policy-making stage. This study is limited to trip production and their impacts through the modelling steps. Further studies should also focus on more detailed interpretation of simulation results for the purpose of policy analysis, or for future estimation of suppressed demand.

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