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Need-based travel behavior analysis: new potential for mobility survey

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Abstract

This paper defines a need-based theoretical framework for evaluating transport policies and investment. It focuses on the assessment of personal transport needs as a fundamental part of human rights and social inclusion. The paper starts by elaborating a need-based methodology, where users' satisfaction together with the identified time threshold define types of trips (i.e. origin-destination, purpose, mode, and distance), which help to identify if mobility needs are covered or not. This paper focuses on how to use traditional survey mobility data for checking the satisfaction of users' needs. The dataset includes the mobility survey carried out in the Barcelona Metropolitan Area during 2013. The results aim to show planners and policy makers where to direct their policies and transport investments in public transport networks and services.

Keywords: People's needs mobility Survey; time threshold; measuring inaccessibility.

1. Introduction and background

During the last decades the main concepts and aims of the transportation planning process have, slowly but steadily, changed to a much more accurate planning taking into account new thoughts and ideas (Kaplan et al, 2014). Terms such as equity and social inclusion have been introduced in this process as well. Moreover, this planning process analyzes the benefits that users receive from transport investments. The problem concerning benefit evaluation is the definition of the level-of-service that a transportation system should provide for the equity and satisfaction of individual needs (Litman, 2002).

In the current literature, various approaches have been proposed to estimate population benefits. These benefits may be weighted differently depending on given groups of the population, their location, their transport services

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availability, their socio-economic level, their age, their gender, etc. (Church et al., 2000). The complexity and the variety of these factors, linked to the fact that they are referring not only to quantitative concepts, but also to qualitative characteristics, make the transport benefits assessment difficult to define through the current Cost Benefit Analysis (Di Ciommo and Shiftan, 2017). As a consequence, in recent years several indicators for capturing equity and social inclusion issues in transportation have been defined. Among them, probably the most widely used, are those dealing with the accessibility concept (Geurs and Van Bee, 2004, Paez et al., 2012, Farber et al. 2014, and Wang et al., 2015). The advantage of accessibility indicators is to embed several characteristics of the transport-land use system in one indicator. By doing so, they can provide a comprehensive assessment of the accessibility 'service' received by the population (Martens, 2015).

Therefore, they have long been introduced in the transportation planning literature as indicators of the quality of services (Ben Akiva and Lerman, 1979). While definitions vary (Miller, 2007), accessibility is generally described as the ease with which a place in a given area is reached by users that need to carry out a given activity, in the literature, referred to as Passive Accessibility (Cascetta et al. 2016).

Relevant studies have shown that the transport system is perceived as essential for responding to key human needs in terms of safety and security in health, employment and social stability, in particular among low-income households. Failing to achieve these needs may result in physical, social, geographical, and economical social exclusion (Lubin and Deka, 2012). Therefore, in order to come up with more equitable transport/urban plans, assessment approaches should include need-based methods, which offer the opportunity for various population groups to express their needs. However, eliciting real needs of people is very challenging, because it can be difficult for them to express what they find necessary and important for improving their quality of life. It would be useful to collect data on the needs of people, the extent to which these needs are satisfied by the activities people conduct, as well as the activities they think would help them to accomplish their needs, but for some reason they cannot implement.

Finally, the reasons why specific needs might not be satisfied should be investigated by activity type and activity attribute level (i.e. location, travel time to join them) (Psarra et al., 2013). This would indicate to planners/policy makers where to direct their interventions, in order to help those people to meet their needs. Therefore, the work is focused on unsatisfied needs and explores the activity attributes/factors that could be improved in order to increase the extent to which those needs are satisfied (e.g. travel time to access activities).

Firstly, this manuscript presents the proposed inaccessibility index for assessing the lack of accessibility to needed activities. Secondly, it estimates the inaccessibility for two groups of the population: (i) the retired-elderly and (ii) housewives. Both are the socio-economic categories that have difficulty in covering their needs in terms of health care services and food shopping respectively.

2. Methodology

This research:

- Focused on people's needs that are unmet because of transport constraints;
- Explored travel attributes of a specific activity (i.e. work, food shopping, health care), and checked how these attributes could be improved in order to increase the extent to which those needs are satisfied.

This research adopted an innovative methodological approach by using existing mobility survey data designed to identify the mobility patterns of inhabitants and their satisfaction or dissatisfaction related to attributes of their travel and activities (i.e. travel time, travel cost, parking availability, crowding in public transport, public transport quality of service, potential destinations, additional transport mode availability). The users' satisfaction level, together with the identified time threshold associated with each characteristic of a trip (i.e. including origin, destination, purpose, public and private transport modes, and distance) identified if the needs of users, are covered or not.

A transport system can be a factor of exclusion and inequity when, for example, the low accessibility to the public or private transportation systems prevents a user from reaching an activity (O'Sullivan et al., 2000). Therefore, it becomes necessary to establish a level of accessibility to ensure that a transportation system can be considered fair and socially inclusive for various groups of the population. Following this idea, the perspective has been widened to include population groups with a limited mobility opportunity choice set (Martens and Di Ciommo, 2017). This interest is reflected in various contributions present in the literature about the links between transit provision, time-poverty and social exclusion (Ferguson et al., 2012, Lucas et al., 2011) which are described, for example, for the whole population (Di Ciommo and Lucas, 2014), disabled (Delbosc and Currie, 2012), and by gender and low-income populations (Lubin and Deka, 2012). Depending on the specific group of the population and on the type of activity, the level of accessibility changes. Various contributions have analyzed the access to key life activities such as health care (Mao and Nokorchuk, 2013), food/supermarket (Widener et al., 2015) or other social activities (i.e. visiting family or friends) (Cascetta et al., 2015).

The basic idea of the proposed IA index consists in defining a time constraint that limits the set of accessible activities, using the current transport system, public, private and non-motorized. The inaccessibility index proposed in this paper is based on the idea that accessibility indicators can provide a comprehensive assessment of the accessibility 'service' available to the population and can be used to elicit the real needs of people to access necessary activities. Technically speaking, the proposed inaccessibility index is based on the one proposed by Cascetta et al. (2015) and adapted to our case study.

The starting point is the definition of the travel time thresholds, representing the travel time with which users are satisfied when achieving an activity. Therefore, these thresholds represent the travel time beyond which an activity is considered inaccessible by users. The definition of these thresholds is based on user satisfaction. Actually, in the literature the need for transport is estimated by the lower degree of satisfaction (Arentze, T. A. and Timmermans, 2009). Each trip-type considers the origin and destination, trip purpose, transport mode and trip length. Each typology of trip is associated with an estimated travel time threshold derived by the average or median of the travel time of various trips of the same typology.

Once the time thresholds have been defined for each trip type, the in-accessibility index, IA, is computed in the following way, according to Equation 1:

$$IA_{o,d}^{m,p,l} = 1 - \frac{\sum_{d=1}^{n} TT_{o,d}^{m,p,l} * \sum_{i=1}^{j} NU_{o,d}^{m,p,l}}{\sum_{i=1}^{g} NU_{o,d}^{m,p,l}} \quad (1)$$

where:

- m represents the transport mode; p the trip purpose; l the length; o the trip origin and d the trip destination;
- TT is the time threshold defined for a given trip typology; it is equal to 1 if the travel time is less than or equal to the time threshold. Otherwise it is 0;
- NU is the number of users making a given trip;
- n is the number of considered typologies;
- j is the number of users making the same trip and that are satisfied;
- g includes the number of both groups of satisfied and unsatisfied users, that are carrying out the same typology of trip.

This index allows us to differentiate between the inaccessible and accessible activities. Therefore, when the IA index decreases, the accessible activities set increases: a value of the index equal to zero means that people can reach the activities they need to carry out.

3. The case study: Barcelona Metropolitan Area (BMA)

This section introduces the case study and implementation of the previously defined index. The index evaluates when people can or cannot reach the needed activity, where the need is measured by a low degree of satisfaction by users with respect to their current travel time to get to the needed activity. Upcoming need-based appraisal methods in transport indicate the satisfaction of these needs, such as a measure of equity (Aretze and Timmermans, 2009). Therefore, the implementation of the proposed indicator of inaccessibility in the Eastern part of the Barcelona Metropolitan Area, will open up a debate on how to focus actions on this geographical area characterized by a lower level of public service, low income, and a population at risk of social exclusion (Cebollada, 2009).

3.1. The Eastern BMA

Four municipalities in the Eastern part of the BMA were identified based on three main criteria: level of income, population profile, and public and private transport level-of-services. They are: Cerdanyola Del Vallès, Sant Adrià de

Besòs, Montcada i Reixac and Santa Coloma de Gramenet. The BMA, better known as Greater Barcelona, is a territorial entity operating on the principle of the metropolitan municipality composed of Barcelona and 35 neighbouring municipalities. It has a population of 3,239,337 in an area of 636 square kilometres. The target area occupies 10% of the extension of the BMA with a population that is about 5% of the totality of the Metropolitan Area of Barcelona. The more sprawled city is Cerdanyola del Vallès with its 30.60 square kilometres, and a population density of 1883.73 inhabitants per square kilometre, while Sant Adria de Besos is the most compact city (3.90 square kilometres with a population density of 8758.21 inhabitants per square kilometre), and Santa Coloma de Gramenet is the most dense city with a population density of 17,017.46 inhabitants per square kilometre over 7.10 square kilometres (IERMB, 201e2). The level of income of this area is between 21% and 30% lower than Barcelona city, while it includes between 35% and 43% of retired people.

These municipalities were chosen not only because they are close to each other and differ in terms of urban typology, population profile, population density and level of income, but also because they have a different quality of public service with a reduced number of metro and regional railways stations (i.e.1 to 7), and a diverse number of bus lines (between 10 and 18 each).

Equity and inequality is best evaluated at a smaller geographic scale. The proposed methodology was, therefore, implemented in small scale areas related to the identified centroids. Fifteen specific analysis zones (AZs) were created. Specifically, six AZs for Cerdanyola del Vallès, three for Montcada i Reixac, two for Sant Adrià de Besòs and four for Santa Coloma de Gramenet. Each AZ is indicated with the first three letters representing the name of the municipality and a number (i.e. 1 to 6). For example, the AZ number 2 of Sant Adrià de Besòs has been identified by BES02. Figure 1 shows the identified AZs.

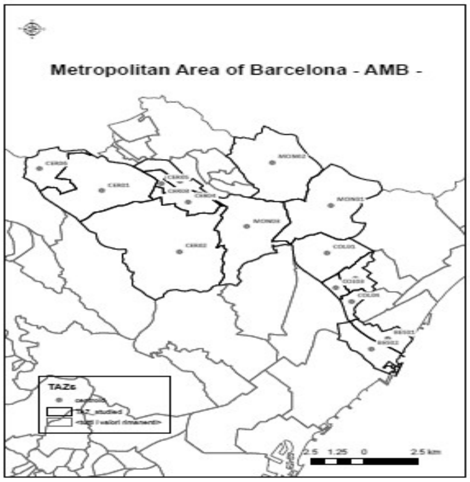

Figure 1. Case study area and map of the Analysis Zones.

3.2. The Dataset

This study applies the proposed index to the data obtained from the Mobility survey carried out by the Institute of Regional and Metropolitan Studies of Barcelona, IERMB, in 2013. The objective of the survey was to identify the mobility patterns of inhabitants on weekdays (Monday to Friday) in the municipalities of the BMA.

The questionnaire used a CATI (Computer-Assisted Telephone Interviewing) method, divided into three parts: (i) the first collected information related to the last trip made the day before the survey (e.g. origin and destination of trip, trip purpose, trip length, transport mode, travel time, etc.). If any trip was made the day before, the interview continued with the evaluation part; (ii) the second part included questions about the user's satisfaction through a 10-point Likert scale; and (iii) the third part dealt with the users' socio-economic information (i.e. age, occupation, etc.) (see Table 1).

Table 1. Dataset and sample description.

Sample Characteristics		Cerdanyola del Vallés	Montcada i Reixac	Sant Adrià de Besòs	Santa Coloma de Gramenet
Variable	*Categories*				
Gender					
	Male (%)	49.4	45.1	46.4	43.6
	Female (%)	50.6	54.9	53.6	56.4
Age					
	4-15 (%)	15.3	17.7	17.1	15.5
	16-29 (%)	13.6	13.4	13.1	13.0
	30-44 (%)	34.0	33.6	32.7	32.5
	45-64 (%)	20.4	20.2	19.6	19.5
	65-74 (%)	14.8	13.0	15.3	17.3
	>75 (%)	1.9	2.1	2.1	2.1
Employment Status					
	Housework (%)	6.8	8.5	6.2	10.4
	Retired (%)	35.0	35.2	42.6	39.2
	Employed (%)	46.9	45.3	41.2	38.9
	Unemployed (%)	11.4	11.1	10.0	11.5

Source: own elaboration from the IERMB Mobility survey

This research was based on data from people living inside the four Eastern Municipalities of the BMA and whose trip purposes included work, study, daily shopping, occasional shopping, health care and visits to family and friends. Transport modes were regrouped into three modes: non-motorized transport (NMT), including walking and cycling; public transport, including bus, metro, tramway, and train; and private transport, including cars and motorcycles, either as a driver or passenger.

After selecting people living inside the Eastern municipalities of the BMA, the initial sample of 16,000 respondents was reduced to 3,162 people. After a preliminary analysis of the new sample, 2,604 respondents had their origin and destination within the boundaries of the study area while 558 respondents had their destination outside of it. This means that most people living in the Eastern part of Barcelona are doing their activities inside the area under analysis. The 3,162 observations were grouped by trip type: people with the same trip purpose, transport mode and trip length were included in the same group. Therefore, 340 different trip types were identified, and for each of them, a time threshold, based on users' level of satisfaction, was identified.

3.3 Time threshold identification

Time thresholds were defined using the data from the second part of the mobility survey, where people were asked to evaluate from 0 to 10 their level of satisfaction with the travel time of their last trip, and to indicate the duration of their trip.

The range of users' level of satisfaction was defined as follows:

- High satisfaction for Likert points between 8 and 10;
- Medium satisfaction for Likert points between 4 and 7;
- Low satisfaction for Likert points between 0 and 3;
- It was assumed that a satisfaction level between 8 and 10 meant that the user was satisfied with their travel time.

Therefore, in terms of the proposed inaccessibility index, this meant a higher accessibility, and consequently a higher satisfaction of their needs.

Table 2 includes some examples of trip-types and associated time thresholds and their statistical mode, average and median values of travel time.

Table 2. Examples of identified Time Threshold TT (in minutes).

Trip typology	Average travel time	Mode of travel time	Median of travel time
CER04_CER06_2_3_2	18.5	15	15
MON01_MON02_1_1_1	10.16	10	10
BES02_COL03_4_2_3	32	30	25
COL02_BES01_6_3_2	28	25	25

Each code (i.e. CER04_CER06_2_3_2 includes : origin_destination_purpose_mode_length

- Origin and destination use the code of identified AZs
- Purposes refer to work=1, study=2, daily shopping=3, occasional shopping=4, medical=5, visit=6
- Mode of transport refers to NMT=1, PUBLIC=2, PRIVATE=3
- Length: 0-5 km=1, 6-15 km=2, 16-25km=3, etc.

Source: Own elaboration from the Mobility survey, IERMB 2013

3.4 Mapping the inaccessibility and eliciting travel needs

For mapping the inaccessibility of a given activity and therefore defining the needs that are not satisfied by the current transport system, a four-step process is proposed. Once the time threshold is identified for each trip-type, the IA index is calculated for each zone, (see Figure 2), obtaining a map of inaccessible activities and zones; then the obtained indexes are differentiated by the transport mode chosen in order to determine which transport alternative provided a lower satisfaction.

Private modes seem to provide a more equitable transport service among the AZs, while NMT (Non-motorized transport) and public transport seem to provide less homogenous quality of services among the AZs. Until now income was not considered as a constraint variable, only travel time. The lower homogeneity of public transport and NMT is partially related to the urban sprawl of this part of the BMA, where public services (i.e. stations or stops) are less because of the lower density of the population.

Generally, NMT seems to obtain the highest degree of satisfaction among all zones and all trip purposes (Figure 3). However, when we analyze the level of satisfaction by trip purpose, we observe that medical and daily shopping purposes receive the lowest satisfaction scores (Figure 2).

The aim of the paper was to elicit people's needs by finding low levels of satisfaction with respect to their travel time (i.e. with a range between 0 and 3). Following the initial assumption that a lower degree of satisfaction of an activity attribute, such as its travel time, means that the travel need is not satisfied, we find population groups with unsatisfied needs (Ingvardson et al, 2017). From an equity perspective, transport policy should mainly address these groups for increasing their activity needs satisfaction. Finally, the degree of satisfaction is the way users can reveal their unsatisfied needs.

Both population groups, the retired- elderly and housewives, cannot satisfy their own needs, therefore they are in a state of non-equity and at risk of social exclusion.

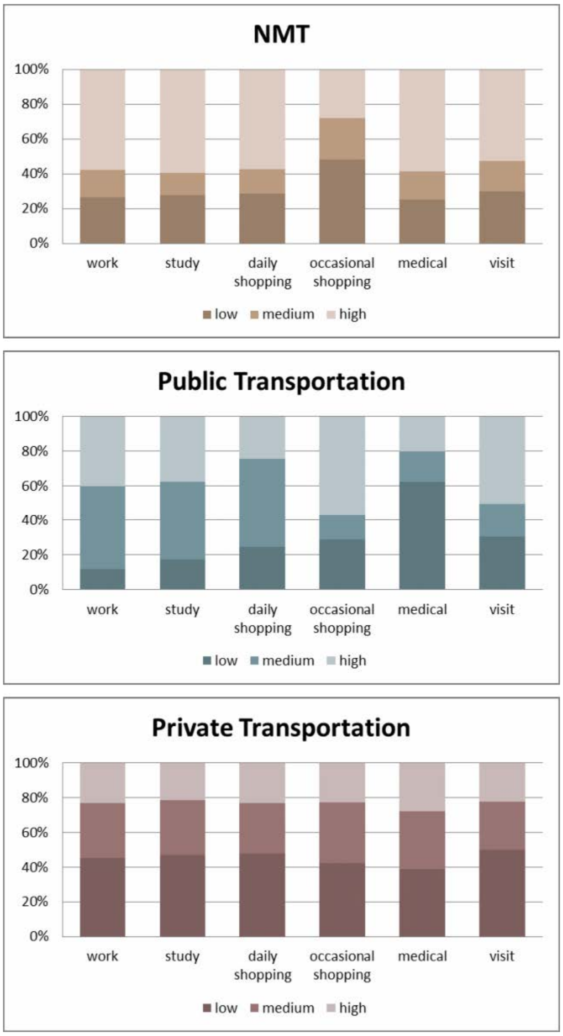

Figure 2. Users' satisfaction of needs by transport modes and trip purposes.

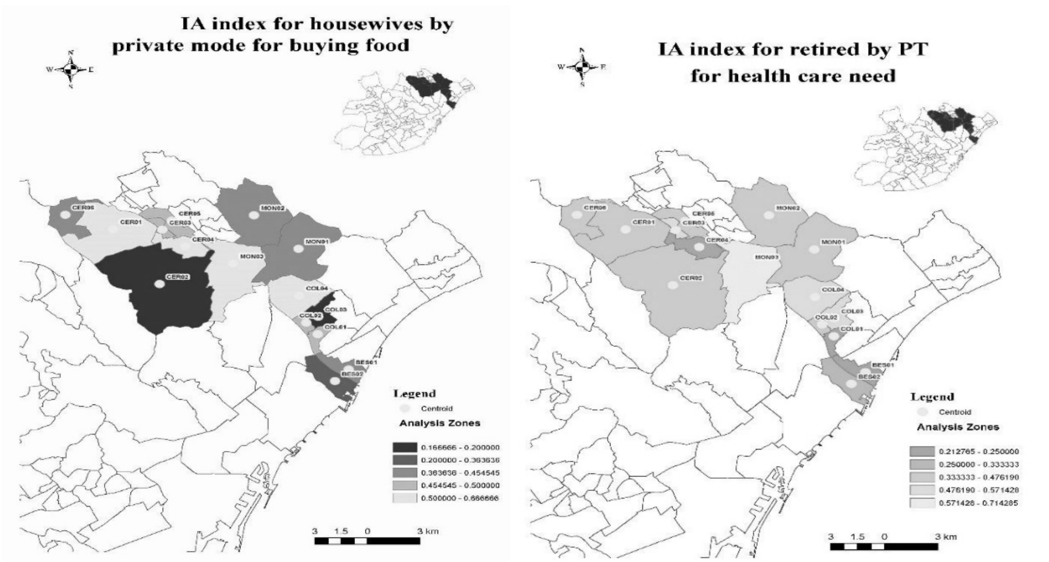

Figure 3. Two groups in need: 1) housewives, in accessing daily shopping; 2) retired-elderly, in accessing health care centers.

4. Discussion and conclusion

The results of this paper show that the proposed methodology, using the revealed level of satisfaction of transport users, is a powerful tool for defining an alternative way to evaluate inaccessibility.

The aim of the paper was to show how to use traditional mobility survey data for carrying out a new type of analysis on inaccessibility.

The two mains objectives were reached, i.e.:

- To offer the opportunity to specific population groups to express their needs by expressing their level of satisfaction;
- To investigate the link between the non-satisfied specific needs and the supply of the transport network and services.

It is a simple method for eliciting the needs of people who are able to indirectly express what they find necessary and important to improve their quality of life. This would indicate to planners/policy makers where to direct their interventions, in order to help people reach their needs. This would ultimately result in a more equitable transport/system, where the main needs of all the impacted population groups are covered.

The proposed method was developed because of the current paternalist appraisal approach where planners/policy makers design alternative solutions and evaluate them based on their own assumptions regarding the needs and preferences of the population. Taking into account the real needs of various population groups in the intervention area would allow the development of more equitable plans and policies.

Two vulnerable population groups, the retired-elderly and housewives, present two relevant uncovered needs: inaccessibility to health care centers and to daily shopping places. Both activities are essential for responding to basic human needs in terms of well-being (i.e. health and food access, Ingvardson et al., 2017).

This way of measuring inaccessibility using the opinion and satisfaction of people with respect to their travel time, an attribute of the activity they need to achieve, allows us to escape from measuring accessibility in terms of space and time without considering the perception of various groups of people with different types of needs.

This framework allows people to express their own opinion as the basis of their inaccessibility index. This result contributes to a new vision of accessibility, revealing personal needs in terms of transport.

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