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AN INTEGRATED ANALYTICAL TOOL FOR EXPLORING THE LINKS BETWEEN JOB ACCESSIBILITY AND SOCIAL EXCLUSION

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This is an abridged version of the paper presented at the conference. The full version is being submitted elsewhere. Details on the full paper can be obtained from the author.

ISBN: 978-85-285-0232-9

13th World Conference on Transport Research

www.wctr2013rio.com

15-18 JULY 2013 Rio de Janeiro, Brazil

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ABSTRACT

Despite growing awareness of social exclusion and equity or fairness issues, transport planning faces a lack of frameworks for analyzing transport projects from the perspective of different user groups and their vulnerabilities. After reviewing literature on the relationship between transport and social inclusion and recent empirical developments in this field, the paper proposes an analytical framework consisting of the joint implementation of a social exclusion indicator and a job accessibility indicator.

In line with contemporary sociological theory, the social exclusion indicator encompasses different socio-economic and demographic factors like income, employment, family and age structure, education, and car ownership. The job accessibility indicator takes into account supply and demand in the labor market and the ease of reaching workplaces, given that employment represents a crucial dimension for social inclusion.

This integrated analytical tool is designed to identify the main beneficiaries of planning strategies and to show the extent to which transport infrastructures or land use changes can reduce access inequity for different social groups. The application of the proposed framework helps the analyst to uncover differences of job accessibility for different social groups by comparing scenarios.

The tool is used to assess the impacts of the planned subway line 6 in Brazil's São Paulo Metropolitan Region. Georeferencing indicator outcomes permits the identification of spatial patterns of exclusion and accessibility in the study area.

Keywords: social exclusion, accessibility, transport policy, public transport

1. INTRODUCTION

Traditionally, the political rhetoric and technical discourse of engineering and transport planning ignore the social effects of land use and transport interventions. Even when recognized, such effects are treated as homogeneous across social groups. In this sense, investments in public transport are automatically understood as belonging to a strategy that makes the most underprivileged groups better off without a cautious examination of the plausibility of such statements.

Since the beginning of the current millennium, efforts have increasingly been made to analyze transport projects with regard to social equity issues. A growing number of articles acknowledge the importance of understanding the organization of transport systems and land use patterns from the perspective of residents and users – particularly of those who are considered socially disadvantaged – and not from the narrow perspective of the transport systems themselves. Social exclusion is increasingly a part of the discourse, the practice and the research agenda in transport planning.

Nevertheless, this awareness is rarely translated into a consistent and reliable analytical framework that could be useful for transport and urban planning practitioners. This paper develops a methodology for assessing the effects of transport projects from the perspective of structurally different social groups. The tool can be used to identify which social groups benefit from transport or land use projects. It can be therefore a basis for assessing plans with regard to equity, since some urban interventions (like public transit projects) should improve the situation of the most disadvantaged communities.

This analytical instrument consists of a social exclusion indicator and a job accessibility indicator. While the former identifies and quantifies a variety of situations of deprivation from a combination of relevant socioeconomic factors in the area of study, the latter expresses the potential accessibility of workplaces by public transportation for the resident population in a given area. The combined use of these indicators allows planners to quantify the impact of a given intervention in the transport system for different social groups in terms of variation of job accessibility – a factor of great importance for social inclusion.

This analytical tool is applied to a case study. The consequences of the planned subway line 6 in São Paulo, Brazil, are evaluated for different socioeconomic segments regarding the accessibility of (potential) workplaces. Hence the accessibility of employment opportunities in the São Paulo Metropolitan Region (SPMR) is compared in two scenarios: without and with the planned line.

The remainder of this article is arranged in four main sections. The next section provides a review of selected literature on social exclusion and its relationship with transport. The key concept of social exclusion is briefly discussed also in context of the area of analysis. The section ends with an overview and discussion of the latest developments in this field. Section 3 presents the methodology employed for analyzing social exclusion and differences in accessibility in São Paulo. It explains how each indicator is built and calculated. In the fourth section, empirical results are presented and interpreted. Finally, the findings are discussed and directions for future research are pointed out.

2. TRANSPORT AND SOCIAL EXCLUSION

In this section, I summarize the most important theoretical aspects on the debate on social exclusion by framing the use of this concept in the context of transport planning. For that, I also discuss the connection between social exclusion and accessibility. This connection lays the foundation for the reasoning behind the proposed integrated approach as against other tools that partition the analysis. Afterwards, I discuss the differences between these analytical methods.

2.1. Theoretical aspects of social exclusion

Coined in France in the 1970s, the term “social exclusion” has gained increasing approval among planners, policymakers, and researchers in recent years for describing contemporary social problems in a more realistic way. Though it may be general, the definition employed by Stanley et al. (2011, p. 198) meets a broad understanding of social exclusion: “social exclusion describes the existence of barriers which make it difficult or impossible for people to participate fully in society”.

Social exclusion refers to a phenomenon that is: a) multidimensional, encompassing several factors like income, employment, health, education, housing, family structures, and neighborhood aspects; b) multilevel since it comprises aspects related to the individual biography as well as to societal structures in several spatial scales; and c) multidisciplinary in the sense that causes and consequences of exclusion are related to distinct policy and research areas.

It is worth noting that the expression “social exclusion” is used to describe both a situation as well as a dynamic process: “Viewed as a process, exclusion directs its glance not only to the affected but also to the actors and agencies of exclusion.” (Kronauer, 2010)[1] Social exclusion refers to a combination of mutually reinforcing aspects of deprivation faced by communities that range from the above mentioned fields, encompassing low educational achievements, poor housing conditions, and low income, among others. Because of the inherent vicious circle processes by which the exclusion from some participation spheres leads to disadvantages in other spheres, the understanding of exclusion presupposes the understanding of interdependences between its dimensions (Wehrheim, 2006).

A controversial question relates to the possibility of and the need for demarcating a frontier between included and excluded, analogous to a poverty line. The dichotomy inclusion/exclusion seems to be attractive because of its simplicity, but should be avoided since it leads us to view the “excluded” in opposition to the included or to society in general. This could lead to an oversimplification. As Lyons (2003) interprets, “social exclusion is not something that has a binary state (i.e. an individual is excluded or is included) but rather that everyone in society sits on a multidimensional scale of exclusion or deprivation”.

Furthermore, definitions vary according to the socioeconomic and cultural context in which they are employed. While ensuring basic human rights and meeting essential needs may

[1] Own translation from the original text written in German.

have a major role in developing countries, these are not the main factors in some developed countries. Because the nature and performance of inclusion agents (social policies, spatial processes like suburbanization patterns, among others) vary across countries and across regions or cities inside a country, a general definition of exclusion should be avoided.

In Brazil exclusion is often related to “denial of citizenship” through the absence of essential public services (Sposati, 1999). There, access to education, social security, health services and decent housing was never guaranteed for all, while in Europe the discourse on exclusion emerged fundamentally after welfare state oriented social policies were cut and with the introduction of the labor market transformations in the 1990s.

In essence, exclusion is understood as a process of breaking social ties and associated, among other factors, with unemployment (long-term unemployment in particular) and the increasing precariousness of labor relations (Kowarick, 2009). Alongside employment, income is a primary dimension of exclusion. Since social exclusion is a broader concept than poverty (understood as the mere inability to acquire goods and services), the former concept is more appropriate for addressing complex social and spatial processes. In locations where public transport is not a sufficient substitute for private transport, car ownership is also seen as another key factor for the unrestricted participation in social activities (Pickup and Giuliano, 2005).

In addition, planners and policymakers need an operational definition of social exclusion. As one can expect, transport planners tend to focus on physical, transport-related dimensions of social exclusion. For analyzing land use and transport-related processes, an operational definition is no less valid if some exclusion aspects or even dimensions of exclusion are set aside (Lyons, 2003). It follows that an important challenge in the transport research field lies in finding an operational concept that could be employed in quantitative methods without losing the essential meaning of social exclusion.

2.2. Exclusion and accessibility

Physical access to key services or activities is not the only component but an important component of ensuring social inclusion. Certainly, personal circumstances (e.g. time budget constraints, cognition skills and physical ability to access transit services, fear of crime and for personal safety, etc.) and other aspects related to the transport provision beyond its mere presence and journey times (e.g. cost of fares relative to wages, lack of service information or poor reliability, number of interchanges, condition of waiting facilities, vehicle accessibility, etc.) are meaningful barrier factors to a full participation in society. Nevertheless, availability of transport services that make key destinations reachable for persons is crucial.

Based on empirical evidence about the role of transport deprivation and of the unequal distribution of activities over the space as triggers for social exclusion, the concept of accessibility has begun to receive more attention. In the United Kingdom a report highlights the facts that people facing social exclusion do not access services and activities and that problems in transport provision are often the cause for poor access to key services or activities, which can reinforce exclusion dynamics (Social Exclusion Unit, 2003). The study explicitly stresses the need to rethink transport planning's analytical tools.

For too long, the focus of planners has rested on the physical operation of transport systems and on finding solutions for optimizing the performance of transport infrastructures. Traditional mobility-oriented planning decisions are seen as having intensified deprivation processes. Therefore, social exclusion issues reinforce the necessity to shift the perspective from the planning-for-mobility approach – with its demonstrated negative consequences for disadvantaged social groups – to another paradigm that is focused more on people's needs (Handy, 2002). Hence transportation researchers and professionals comprehend accessibility as a key concept for dealing with transport-related exclusion. Lucas (2012, p. 106) points out:

> "Furthermore, documenters of the phenomenon are less interested in the fact that there is no transport available to people per se but rather the *consequences of this in terms of their (in)ability to access key life-enhancing opportunities*, such as employment, education, health and their supporting health networks. In this way, there is a move away from the traditional systems-based approach to transport provision, towards *a more people-focused and needs-based social policy perspective.*"[2]

An intuitive definition of accessibility is the ease with which people can access opportunities distributed in space. Typically, accessibility measures consist of a factor of impedance (which reflects the time and/or cost of reaching a destination) and a factor of destination attractiveness (which can be related to the quantity and the quality of opportunities). In this sense, accessibility reflects both mobility options and land use patterns (Handy, 2002; Litman, 2008). In this study, accessibility is defined as the potential of different social groups to access certain activities by a particular mode of transport in order to enhance their participation in society. More precisely, the accessibility measure employed here expresses the potential to travel to workplaces or job opportunities by public transit.

In the UK, the awareness of social exclusion has led to the introduction of accessibility planning. This framework is used to appraise the level and quality of access of key activities with the aim "to ensure a clear and consistent process for identifying groups and areas with accessibility problems" (Lucas, 2004). As outlined above, poor accessibility is often connected with a whole range of other deprivations. Accessibility planning tools usually define reference values e.g. the maximum travel time that it should take citizens to travel from their residence to a school or a hospital. The specific interventions to be undertaken by municipalities – improvements in the supply of transport opportunities, changes in land use, among others – are derived from these goals and guided by the central objective of promoting social inclusion.

2.3. Recent developments in empirical research

As outlined above, several authors express their concerns about the theoretical implications of the exclusion issue in the transportation field, arguing for the need of a paradigm shift in the transport planning and policy process to account for equity considerations in project design and evaluation. Yet only recently some works have begun to explore these questions empirically, suggesting new ways for dealing appropriately with social exclusion issues in

[2] Author's own emphasis.

planning practice. More specifically, the focus of the research agenda on the relationships between transport and social exclusion has moved towards the following issues:

1. The development of analytical models for defining transport-related social exclusion or deprivation (limited mobility and/or accessibility) and for identifying vulnerable social groups or areas

2. The development of tools for ex-ante assessment of transport projects or policies regarding exclusion (often with focus on particular social groups)

3. The development of integrated analytical tools that encompass both above mentioned objectives

In the next subsections, these approaches are briefly presented and discussed on basis of some examples from the literature. The intention is not to provide a comprehensive literature review.

2.3.1. Analytical models of exclusion

Analytical models of exclusion are designed to provide a deeper understanding of social exclusion and/or the behavior of transport-deprived groups in local contexts. These studies usually refer to the "transport disadvantage" issue. Transport-disadvantaged groups are commonly defined as those with poor mobility. It is hypothesized that the reduction of transport disadvantage could improve the chances for social inclusion. Multivariate statistical methods are usually employed in these studies to explore the connections between transport and social deprivation.

Morency et al. (2011) examine the mobility determinants of vulnerable population segments (seniors, low-income and single-parent households) in three Canadian cities on the basis of a spatially-expanded regression model with the average trip distance as dependent variable. Income, household structure, age, car ownership, and occupation are some of the explanatory variables included in the model. The authors identify the association between these factors and trip lengths. They find out, for instance, that seniors living in Hamilton have a significantly lower mobility rate than the average person, and that car ownership is an important factor in explaining travel distances. Interestingly, the study is inconclusive about the effect of proximity to transit nodes. Despite the refined modeling approach that allows controlling for contextual factors, this report has two main drawbacks, however. First, in focusing on particular population segments, it provides only a partial and incomplete view of the mechanisms of social and transport disadvantages. Second, it is focused on the mobility rate – but, from a theoretical point of view, mobility *per se* is not necessarily related to deprivation situations since transport disadvantage is not a synonym of social exclusion.

However, Currie and Delbosc (2010) carried out a quantitative assessment of the relationship between transport disadvantage, social exclusion, and well-being in Melbourne, Australia, and identified strong linkages between social exclusion and transport disadvantage as well as between exclusion and well-being. Transport-disadvantaged groups were those that reported experiencing difficulties in finding, accessing and paying for transport services).

Social exclusion was assessed in five dimensions: income, unemployment, political engagement, participation, and social support.

Based on the same data and following the same theoretical framework, Stanley et al. (2011) define the risk of being socially excluded through an indicator that ranges in a scale from zero to five. Each point on this scale expresses a threshold that a person can fail to cross (for example, if their gross income is less than $500 per week). The estimation results of the generalized ordered logit model suggest that "the risk of someone being excluded is reduced, the higher their connections with community, household income, realized mobility, and level of personal growth" (Stanley et al., 2011) This study accounts for a range of factors linked to the social context and psychological aspects of the interviewed individuals.

2.3.2. Tools for ex-ante project evaluation

Research advances on models of this type are partially based on critiques of traditional analysis methods. In particular, it has been recognized that cost benefit analysis fail by deriving monetary benefits with no regard to distributional and equity considerations. (Lucas et al., 2009; van Wee, 2012) Transport projects are evaluated based on the distribution of accessibility benefits throughout social segments.

Mackett et al. (2008) report the development of a GIS-based model which can be used to identify the more suitable micro-scale policy actions for increasing accessibility to some opportunities e.g. for people in wheelchairs. The tool enables planners to compare, for example, the effectiveness of policy options like implementing dropped kerbs at road crossings or widening the pavement for improving the accessibility level of this particular group. This tool is therefore focused on the physical barrier aspect of social exclusion. This methodology is of limited importance for the objectives of this article because it cannot be used for strategic large-scale planning. Second, the analysis is segmented: only the benefits for the target groups are accounted for. It does not deliver any aggregated social benefit measure.

To analyze transport policies in Bogotá, Bocarejo S. and Oviedo H. (2012) also present an accessibility-oriented methodology, assuming that "accessibility can be used as an indicator of social inclusion and the potential of economic development at an individual level". The authors distinguish between three types of accessibility: realized accessibility (the number of jobs that inhabitants from a particular zone actually reach, calculated from the number of work trips), accessibility given standard parameters (the number of opportunities considering international accepted thresholds like the maximum budget of time or money spent for accessing mandatory activities) and available accessibility under desired preference (which can be calculated based on declared preference data and helps to identify "the level of effort that people make in order to improve their levels of accessibility").

The study has a specific focus on mandatory activities (accessibility to job opportunities) that according to theory have a major role in promoting social inclusion. Within this framework the equity impacts of specific policies (the introduction of a cross subsidy fare system and a new bus rapid transit line) are evaluated. But the authors do not define social exclusion explicitly. Due to the indicators' construction, the concept appears only in an indirect way – through the pressure on budgets generated by accomplished trips.

2.3.3. Integrated analytical tools

On the one hand, the main output of the first type of tools is a better comprehension of the phenomenon of exclusion in a particular context and a highlight on the relationships between social and transport deprivation. They represent important frameworks for a deeper understanding of socioeconomic vulnerabilities. On the other hand, tools for ex-ante project evaluation depart from a broad understanding of social exclusion or from a given definition of which social groups are deprived and evaluate the distribution of the benefits generated by these infrastructures.

Very recently, a new methodological approach has emerged. These tools are designed both for assessing quantitatively of social exclusion (or deprivation) in a specific location as well as to evaluate accessibility outcomes grounded on that meaning of social exclusion. By combining the analytical objectives of the two above mentioned tools, these *integrated analytical tools* generate operational measures of exclusion and accessibility (or transport deprivation) that can be helpful to value the proposed interventions (e.g. a new transit infrastructure) for different social groups. Integrated tools help to identify the main beneficiaries of planning options and assess their equity impacts. Due to the intrinsic relationship between social exclusion and accessibility, this last type of framework is seen as particularly powerful for analyzing social and transport phenomena in accordance with theory.

Jaramillo et al. (2012) investigate the relationship between provision of public transit and social transport needs to monitor the contribution of transport policies to the integration of socially excluded and segregated population groups in the Colombian city of Santiago de Cali. Using a methodology similar to that suggested by Currie (2010), the researchers calculate and compare two measures: an index of social transport needs and an index of disparity between transport need and provision. Relevant components of the indicator of social transport needs and their relative weights are identified through a principal component analysis. Income, car ownership, illiteracy, employment situation, distance to the city center and age structure are found to be significant factors. This index is then compared with an index of public transport provision which expresses the mean density of transport services in an area. Their methodology allows highlighting disparities between transport needs and transport provision. Policy should be directed at reducing such disparities.

3. METHODOLOGY

In this section, I present an integrated approach for evaluating transport projects with regard to social exclusion. The tool developed combines an analytical model for assessing social exclusion with a job accessibility indicator.

The São Paulo Metropolitan Region (SPMR) was chosen for the case study because of data availability and the markedly high socioeconomic inequality in its territory. SPMR consists of 39 municipalities where 19.5 million people live (about 10% of the country's population). However, the approach developed and tested here can be applied in other contexts, although the identification and evaluation of the main factors leading to social exclusion and the operational concept have to be adapted to local circumstances. The proposed framework can be also used for assessing the impacts of land use policies or of comprehensive urban projects consisting of land use and transport interventions for different social groups.

3.1. Social exclusion indicator

In line with the sociological understanding of social exclusion summarized in Section 2, the social exclusion indicator is not based on a single variable but involves multiple aspects related to exclusion situations.

A factor analysis was undertaken to build the indicator. This statistical procedure is useful to examine whether a common background variable exists among the observed variables. The method aims to reduce the high dimensionality of a data base by identifying one or more unobservable factors behind the behavior of the variables incorporated into the model.

To calculate the social exclusion indicator, seven variables directly related to central aspects of social exclusion in the SPMR were utilized. These variables were obtained by processing the data from the most recent Origin Destination Survey (OD 2007) carried out in the region. The data is aggregated at the traffic analysis zone[3] level.

- Proportion of children and young persons in the population (U17) - This variable captures the demographic dimension of social exclusion and reflects its intergenerational reproduction.
- Average size of household (HHSIZE) - Very high number of residents in a household can be a sign for inadequate housing conditions in the context of the examined area.
- Average income per capita (INC) - The average monthly income per capita serves as a measure of economic welfare. The higher the income, the less vulnerable to social exclusion one tends to be.
- Proportion of illiterates and population without school degree (EDU_0) - Illiteracy represents a strong deterrence factor to social participation in general and full involvement in the labor market.
- Proportion of population possessing higher education degree (EDU_4) - It is hypothesized that high education level (university degree) increases the chances of social participation.
- Unemployment rate (UNEMP) - This variable corresponds to the proportion of residents that reported being unemployed among the employable population. Participation in the labor market plays a crucial role not only for income generation but also for a social participation in a broader sense.

[3] The traffic zones employed by the OD survey are very heterogeneous in size (ranging from 0.31 km^2 to 522.31 km^2) and population (ranging from 0 to 395,472 inhabitants).

- Proportion of households without a car (NOCAR) - Not owning a car can mean a serious mobility limitation, depending on locations people want to reach, and because of the deficient public transport provision.

Table 1 – Pearson correlation coefficients* of variables encompassed by the social exclusion indicator

	U17	HHSIZE	INC	EDU_0	EDU_4	UNEMP	NOCAR
U17	1.00						
HHSIZE	0.68	1.00					
INC	-0.75	-0.70	1.00				
EDU_0	0.80	0.66	-0.75	1.00			
EDU_4	-0.80	-0.68	0.96	-0.78	1.00		
UNEMP	0.49	0.51	-0.52	0.48	-0.52	1.00	
NOCAR	0.60	0.33	-0.75	0.63	-0.75	0.43	1.00

* All coefficients are statistically significant at 0.001 level

For variables that are highly correlated with each other, it is assumed that there is a common background factor. As reported in Table 1, significant statistical correlations between most of the variables are observed. Values equal to or greater than 0.75 (in module) can be identified between the proportion of children and young people, average per capita income and educational level variables.

Using the method of principal components whereby linear combinations of original set of variables are performed, a factor has been identified that alone accounts for 70.5% of the variance of the seven original variables. This factor was the only one that could be extracted based on eigenvalues greater than 1. It was called “social exclusion indicator” (SEI) – a z-standardized variable (with zero mean and a unitary standard deviation). Statistical tests pertaining to the factor analysis were performed, as a Kaiser-Mayer-Olkin measure of sample adequacy (0.84) and a Bartlett test of sphericity ($\chi^2 = 2{,}994.55$; df = 21; $p < 0.001$). These results corroborate the suitability and the sufficient degree of correlation in the sample for the factor analysis.

Factor loadings (the correlation coefficients between the factor and each of the variables) and communalities (the portion of variance of a single variable explained by the factor) are reported in Table 2. The variables related to the demographic composition, to income and to education level are particularly well assessed by the indicator.

Table 2 – Factor loadings and communalities of variables encompassed by the social exclusion indicator

Variable	Factor loading	Communality
U17	0.881	0.777
HHSIZE	0.777	0.603
INC	-0.935	0.874
EDU_0	0.877	0.769
EDU_4	-0.949	0.900
UNEMP	0.650	0.423
NOCAR	0.768	0.590

Thus, each spatial unit of OD 2007 can be associated with a value that summarizes a set of vulnerabilities suffered by its population in the fields of work, education, mobility, income, housing and family structure. Since data is missing for some traffic analysis zones, the SEI values were calculated for 423 out of the 460 zones.

Finally, based on ranges of one standard deviation above and below the mean, classes of social exclusion were established. The resulting five categories were numbered 1 to 5, where 1 represents the lowest and 5 the highest degree of social exclusion.

The creation of the social exclusion indicator by this method allows identifying the relevant variables for exclusionary processes loyal to theoretical considerations and on locally available empirical data. As expected, the model does not address all aspects of social exclusion, but certainly the indicator comprises crucial factors of how social exclusion manifests in the SPMR. Furthermore, it was possible to generate a variable that reflects a continuum of deprivation. Thus, this approach avoids focusing only on certain population groups or stamping some groups or regions as excluded in opposition to others.

3.2. Accessibility indicator

Built up on the exclusion indicator, the second component of the analytical instrument is an accessibility indicator. Here, the focus is on labor market accessibility by public transit, since participation in the labor market is decisive for social inclusion according to theory.

Corresponding to the great diversity of definitions of accessibility, there are dozens of possible indicators. Bhat et al. (2000) present several of these measures, while Geurs and van Wee (2004) seek to systematize them into categories and provide criteria to guide the development or the choice of indicators. Especially two of these criteria are of central importance within an accessibility analysis to employment opportunities:

1. Criterion A: When demand for a particular activity opportunity with limited capacity increases, the accessibility of this activity will decrease.
2. Criterion B: The increased number of opportunities for a particular activity in a region should not influence the accessibility of individuals unable to or prevented from participating in this activity.

Criterion A draws attention to the restrictions in the supply of certain opportunities and urban facilities with respect to their demand. Jobs are offered in limited numbers, which reinforces the importance of this criterion. Shen (1998) shows that results can be biased if competition effects in accessibility analysis are ignored. A large number of accessibility indicators do not meet this criterion and were therefore discarded.

Criterion B induces a qualitative differentiation of existing opportunities. In an analysis of accessibility to work, it is extremely important to consider the segmentation in the labor market. It shall be ensured that the destination opportunities reflect the needs of the residents. In fact, the increase in supply of employment opportunities in a particular segment of the labor market should not have any relevance for workers who - depending on level of education, qualification and work experience, among other factors - act in another segment.

Accessibility levels are calculated using a modified version of the gravity-based indicator. This kind of indicator weighs opportunities by impedance (Handy and Niemeier, 1997). But, in addition to attractiveness and repulsion factors related to urban structures and transport network, the indicator also takes into account competition in the labor market. Based on the formula presented by Wang (2003), the job accessibility A of workers residing in a given traffic zone i and belonging to the segment g of the labour market is algebraically defined by:

$$A_i^g = \sum_{j=1}^{J} \frac{O_j^g . f(t_{ij})}{\sum_{k=1}^{K} W_k^g . f(t_{kj})}$$

where A_i^g is job accessibility for residents of i for opportunities of economic segment g
O_j^g is the number of job opportunities in segment g and zone j, $j \in J$ (total number of destination zones)
$f(.)$ is the impedance function
t_{ij} is the travel time from zone i to zone j
W_k^g is the number of workers in segment g that reside in the zone k
t_{kj} is the travel time from zone k to zone j

Labor market segmentation follows a classification compatible with that adopted by OD 2007. Four segments were considered: industry, trade, specialized services – the latter resulting from the integration of the categories credit and financial services, healthcare, education services and specialized services - and other services. Together, the first three segments account for more than half of jobs for each of the five classes of social exclusion and for the SPMR as a whole. The accessibility level of a zone results from the average of accessibility measures in each of the labor market segments. This average is weighted by the proportion of zone's inhabitants working in each segment.

To calculate travel times between the traffic zones in the SPMR by public transit, data from the OD 2007 and network data provided by the local transport agency São Paulo Transportes were fed into a public transit network model. Impedance was specified as a negative exponential function, since this specification fits the empirical data better than the potential form. The estimated parameter value (-0.054) was used in the base scenario and in the scenario with the modeled metro line 6.

With the data available, the accessibility indicator was calculated for 393 out of the 460 traffic zones. After calculating accessibility to jobs for the resident population of each traffic zone, the results were aggregated to all areas of a particular category of social exclusion. On this basis, equity considerations can be made.

For the before-and-after comparison, the indicator was calculated twice for each traffic analysis zone (with the actual travel time matrix and with the estimated travel times after in the scenario with the new subway line). Population and the number of job opportunities in the region were hold constant in both scenarios. If the purpose were to assess land use projects (e.g. a mixed-use development), then one should alter the values of job opportunities for calculating accessibility values for the suggested scenario.

The indicator is quite difficult to interpret because it accounts for several factors. Particularly due to the introduction of the competition component (the denominator of the accessibility formula), counterintuitive values can be generated in the sense that reduced travel times between zones of residence and work do not necessarily lead to higher accessibility scores because they can be counterbalanced by other factors taken into consideration (particularly the travel times that other residents need to commute to their potential workplaces).

4. EMPIRICAL RESULTS

For a better understanding of the meaning of social inclusion and exclusion in the context of SPMR, Table 3 displays the mean values of the seven variables included in the statistical model. As expected, all values have a monotonic behavior across the different exclusion categories. The high contrast between these values is an evidence for structural differences between areas belonging to different categories. Therefore, inhabitants of areas with social exclusion class 5 (in brief SEI 5) are more susceptible to social exclusion than residents of areas in other SEI categories.

Table 3 – Mean values of variables of the social exclusion model grouped by SEI categories

Variable	SEI 1	SEI 2	SEI 3	SEI 4	SEI 5	SPMR (mean)
U17	10.3%	12.6%	18.0%	24.4%	30.3%	21.6%
HHSIZE	2.6	2.8	3.1	3.6	3.8	3.4
INC (*)	2,326.80	1,747.56	1,050.84	582.09	424.65	900.94
EDU_0	6.8%	9.5%	14.9%	23.2%	31.0%	19.8%
EDU_4	56.8%	43.5%	21.9%	7.3%	3.0%	17.2%
UNEMP	7.0%	8.0%	9.6%	12.4%	16.4%	11.5%
NOCAR	24.4%	27.1%	40.1%	51.1%	61.4%	45.6%
Number of zones	11	63	115	160	74	423

(*) Monetary values expressed in Brazilian Reais (R$) as of October 2007

Figure 1 shows that social exclusion in the SPMR follows a clear spatial pattern: as expected, peripheral neighborhoods and municipalities other than São Paulo register the highest exclusion levels while the regions with lower levels are in general located closer to the city center of São Paulo (within a radius of 20 kilometers).

The planned subway line 6[4] will connect districts in the northwest of the city to its center. The new line will offer transfer possibilities to the existing subway lines 1 and 4 as well as to regional train lines. Neighborhoods with different socioeconomic profiles will be directly served by line 6 as also displayed by the map. Due to its radial geometry in an urban space

[4] In this paper the subway line 6 was modeled as stated by the Companhia do Metropolitano de São Paulo in October 2010. The planned line has 14 stations and a total length of nearly 16 km.

marked by the center-periphery divide, one can expect the transit infrastructure to promote an increase in accessibility of underprivileged social groups in higher proportion than the accessibility of more affluent groups. In this case, line 6 would be a project that contributes to a more even distribution of accessibility to job opportunities.

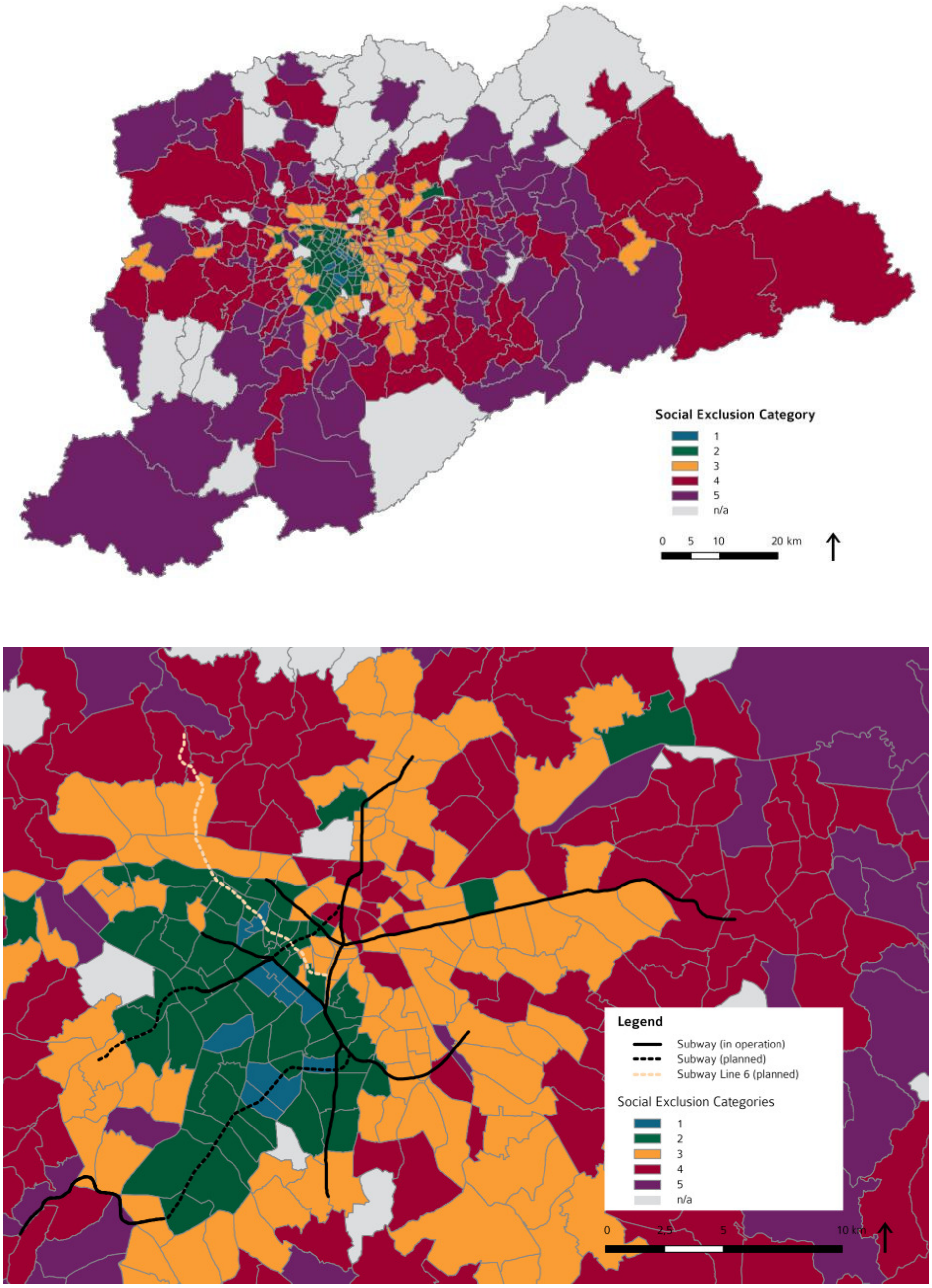

Figure 1 – Distribution of the TAZ according to social exclusion categories (overview and zoomed central area with subway network)

The maps in Figures 2 and 3 exhibit accessibility levels in the SPMR in two situations, respectively: without line 6 (current scenario) and with line 6 (planned scenario). As the indicator of potential accessibility combines factors of attraction and repulsion, producing a dimensionless numerical result, its interpretation is relatively difficult. To facilitate reading of results, it was decided to establish ranges of values based on the average accessibility

(0.94), which is the same for both scenarios. Three intervals above average and three intervals with values below average were created. The same classification classes were employed for displaying the results of both scenarios.

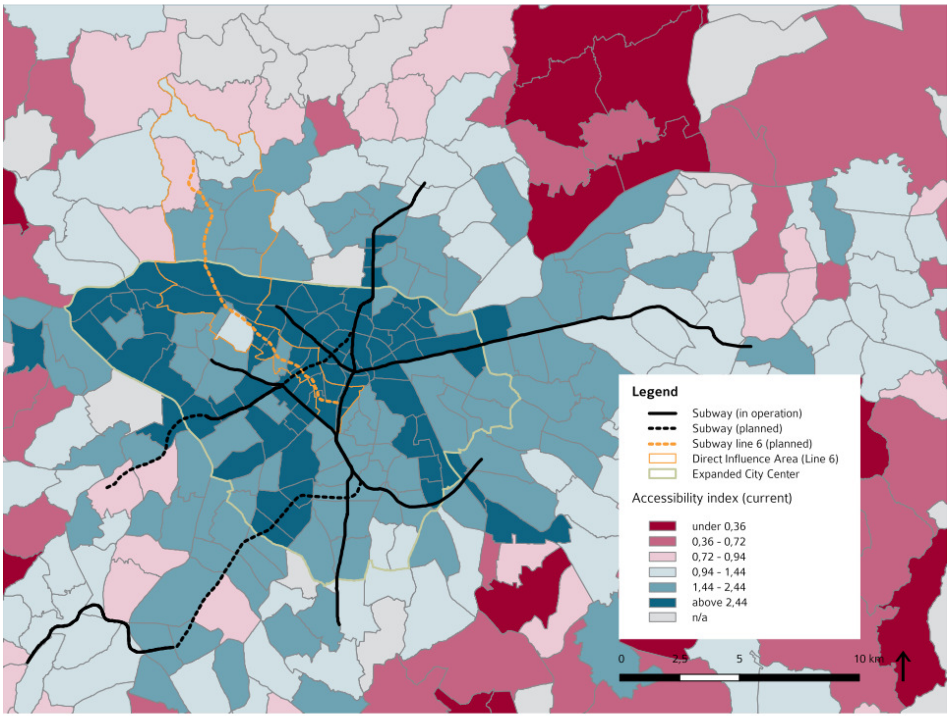

Figure 2 – Job accessibility at TAZ level (current scenario, without subway line 6)

At the metropolitan level, one notes the relative advantage of the population living in central areas with respect to accessibility to workplaces, while many of the outer traffic analysis zones have low accessibility. This fact is related both to the concentration of transportation service provision and to the concentration of employment opportunities in the centrally located areas of the metropolis. This result gives empirical support to the fact that transport disadvantage is also highly concentrated in the outskirts of the analysis area, overlapping with the areas of higher levels of social exclusion.

Almost all traffic zones that are to be directly served by subway line 6 already have accessibility values above average in the current scenario (the only exception is Vila Morro Grande, with an index of 0.92). The highest accessibility scores in this group are recorded for traffic zones Lapa (4.43), Água Branca (3.71) and Baixa Lapa (3.46), already served by regional train lines.

It is also important to highlight the role of rivers Tietê and Pinheiros (which watercourse delimits the Expanded City Center in the north and in the west) as determinants of accessibility boundaries in the metropolitan space. Neighboring areas separated by one of these natural barriers may present markedly different accessibility values. Furthermore, one can observe the potential of rail transportation infrastructures as accessibility promoters in this area of study. Almost all traffic zones served by the subway system have quite high accessibility levels.

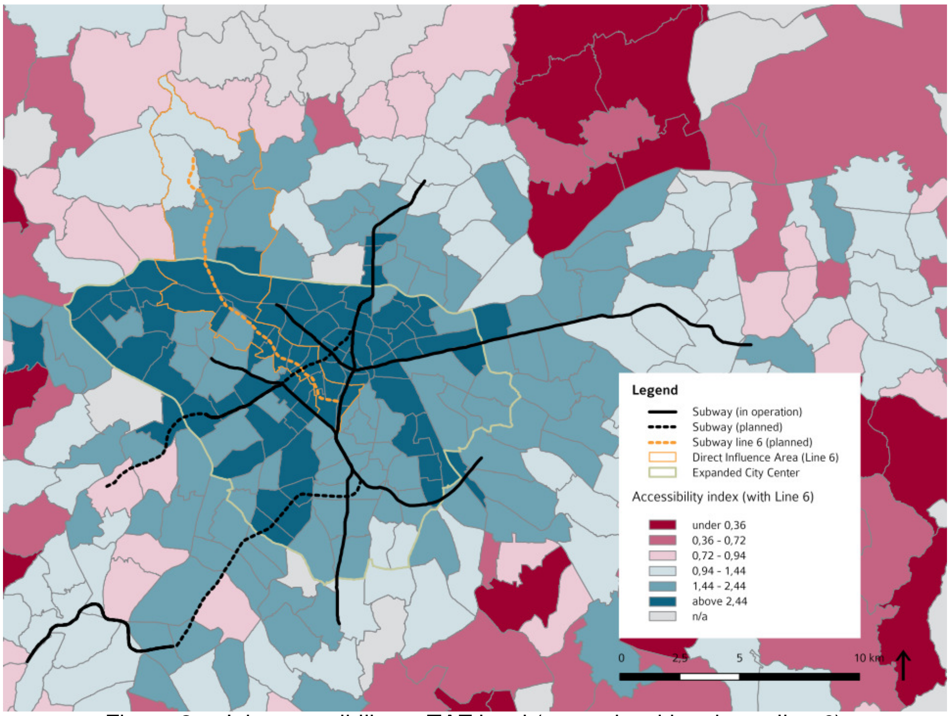

Figure 3 – Job accessibility at TAZ level (scenario with subway line 6)

However, as illustrated by the very slight differences between the maps, the commissioning of line 6 does not change substantially the inequity situation regarding accessibility levels. In the future scenario (Figure 3), even the residents of the northwestern city neighborhoods (those who will reside near the line 6) shall continue to experience lower levels of job accessibility than those residents of the central regions.

To highlight the difference between the two scenarios, Figure 4 exhibits the percentage variation of accessibility index (recall that the overall accessibility is the same in both scenarios). The most significant accessibility growth rates (above 10%) shall be concentrated in the zones directly served by line 6. A continuous area extending from Liberdade to Pompeia (the darker areas close to the city center shown in Figure 4) shows positive changes in the accessibility indicator. However, several regions which do not lie along the axis of the planned line (mainly in the south and southwest of the City of São Paulo) shall also experience substantial gains in accessibility. This result suggests that residents of neighborhoods close to the existing metro lines shall have shorter commuting trips and in this sense also benefit from the expansion of the network. On the other hand, some areas directly served by line 6 shall experience relative reductions in accessibility of workplaces despite the new transportation service because of the competition factor (one need even less time to get to job opportunities when travelling from other zones).

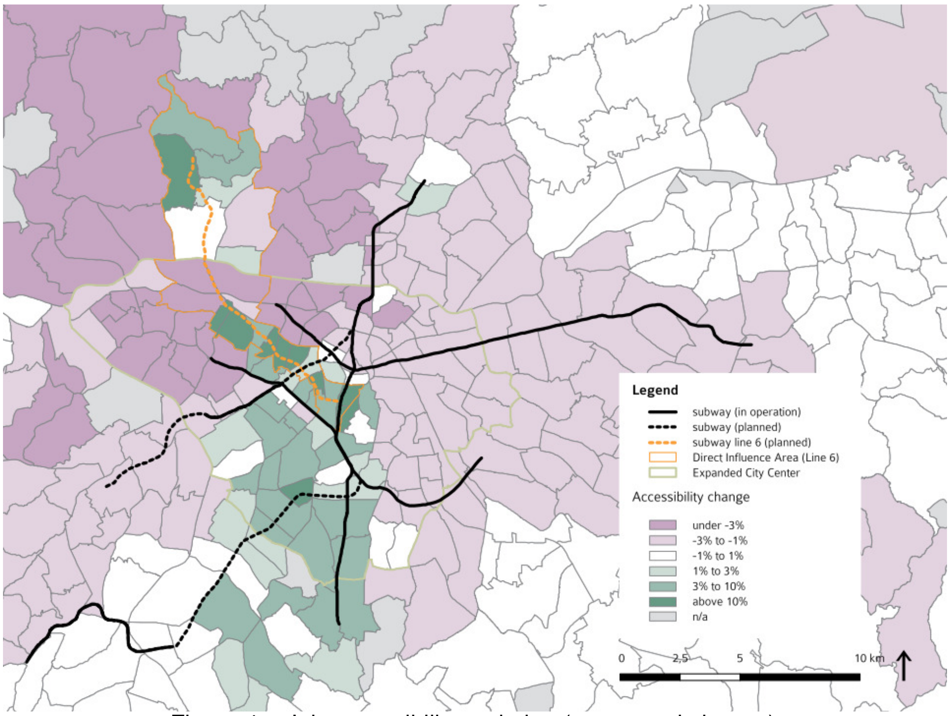

Figure 4 – Job accessibility variation (percentual change)

Table 3 summarizes the results by grouping the accessibility indicator values of traffic zones by the classes of social exclusion to which they belong in both scenarios. The inhabitants of SEI 1 areas have, on average, a level of accessibility to workplaces clearly superior in comparison to residents of regions associated with other social exclusion categories. The value is 4.6 times larger than the accessibility of the most excluded social groups.

A comparison between values of both scenarios shows that, with the introduction of the new subway line, the inequality in accessibility between different socioeconomic profiles would not decrease as one could expect, but increase. It means that, in the metropolitan context, the sole introduction of the new subway line 6 is not able to diminish the current inequality in access to job opportunities. While the accessibility indices for social groups less subject to exclusion increase positively by up to almost 5%, the accessibility of large portions of the most vulnerable population decreases moderately. This shall occur because the new public transit project alters significantly the travel time to work only for a minor share of the most excluded population in the area of study. In general, groups that currently have lower accessibility levels will not benefit significantly from the new subway line.

Table 3 – Accessibility of TAZ grouped by social exclusion categories

Social exclusion category	Accessibility (current scenario)	Accessibility (future scenario)	Percent
SEI 1	2.76	2.89	+4.8%
SEI 2	2.19	2.25	+2.8%
SEI 3	1.36	1.36	-0.4%
SEI 4	0.83	0.82	-0.8%
SEI 5	0.60	0.60	-0.2%
SPMR	0.94	0.94	0.0%

5. CONCLUSIONS

Among the few empirical studies on the link between transport and social exclusion, "integrated analytical tools" cope appropriately with the link between transport and social exclusion for assessing ex ante the impacts of transport planning options for different social groups. This kind of analytical tool operationalizes the multidimensional concept of social exclusion and is helpful to identify deprived groups in a specific context. Building on this, the distribution of transport benefits (for instance, represented by measures of accessibility to key activities) is evaluated. This approach draws attention to fairness by the distribution of benefits generated by such urban interventions across social groups.

The integrated analytical instrument outlined in this article quantifies the effect of changes in the transport system (as in the case study of the subway line 6 in the SPMR) and/or in land use in terms of variation in job accessibility for groups belonging to different social exclusion categories. The proposed tool represents a consistent framework for adequately addressing the social exclusion perspective. Since the required data is promptly available for several cities and the calculations can be done without advanced mathematical knowledge, the tool can be easily implemented by decision-makers willing to understand the social equity of their transport and urban planning decisions.

In the São Paulo Metropolitan Region, most excluded groups (which typically reside in neighborhoods far from the most employment opportunities and not served by the subway) are shown to have significantly lower levels of job accessibility than less excluded groups. The planned subway line 6 changes this picture only marginally.

The new infrastructure improves job accessibility for residents of the central areas and of areas directly connected to the subway. Many zones in the northwest of the city that lay relatively close to the new line and are marked by high exclusion levels have to account for significant accessibility losses. From a general standpoint, residents of highly excluded areas register a slight decrease in accessibility to work, compared to the current scenario, due to the concurrence in the labor market captured by the accessibility indicator. Moreover, as seen in Figure 4, not even all the areas served directly by line 6 show positive variations in accessibility. These results contradict the typical planning discourse that refers to the generally positive effects of public transport projects. An interesting question for further research would be: Which transport or land use intervention would better contribute to close the job accessibility gap in the SPMR?

It is also important to define the limits of the analysis, which is not intended to cast doubt on the importance of this transportation project for the access to other urban facilities and for the integration of urban peripheral regions. For providing a complete picture of the role of transport for social inclusion, accessibility of other activity purposes (e.g. health services, education etc.) and by other transport modes (e.g. private motorized modes, on foot as well as multimodal trips) shall be considered. This study focuses on public transit, even though individual motorized and non-motorized modes are important alternatives for the SPMR. For an overall assessment of the considered project economic and environmental considerations should be included, for instance, in a multicriteria analysis framework.

Moreover, it should be emphasized that the accessibility analysis is based on only four economic sectors. More accurate results can be achieved using appropriate datasets which take into consideration the complex structures of the metropolitan labor market in a more rigorous way. Alternative impedance function specifications should also be tested, for instance adding an affordability component as a variable representing the travel money budgets, as implemented by Bocarejo S. and Oviedo H. (2012).

Furthermore, the accessibility indicator is to be understood as a measure of potential access to activities (in this case jobs). It says nothing on whether these activities are effectively accessed or not. The potential accessibility indicator could be complemented by a measure of the potential time savings of commuting trips to the actual workplaces based on microdata.

The results reinforce the importance of integrated planning that takes into account the interdependences between the transport system, land use patterns, and social structures. The development of tools aligned with "accessibility planning" and promoting urban development based on compact structures (with mixed-use developments that favor a more equitable distribution of activities in space and reducing travel times) could contribute to increased levels of accessibility among segments of the population that are most exposed to processes leading to social exclusion.

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