Een index om het risico op bereikbaarheidsarmoede te meten

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Samenvatting

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Bereikbaarheidsarmoede

Bereikbaarheid is een essentiële voorwaarde voor deelname aan activiteiten buitenshuis, zoals werk, onderwijs en medische zorg. Steeds meer onderzoek laat zien dat gebrekkige bereikbaarheid de deelname van bepaalde bevolkingsgroepen aan activiteiten belemmerd. Zij ervaren zogenoemde vervoersgerelateerde sociale uitsluiting, als gevolg van inadequate vervoersystemen of hoge kosten van vervoersdiensten. Vanuit een perspectief van rechtvaardigheid zou een eerlijk vervoersysteem alle bevolkingsgroepen, ongeacht bijvoorbeeld autobezit, moeten voorzien van een *toereikend* bereikbaarheidsniveau om volwaardig deel te kunnen nemen aan de samenleving. Bij een bereikbaarheidsniveau onder dit toereikende niveau – in andere woorden: onder de zogenaamde *bereikbaarheidsarmoedegrens* – lopen mensen het risico op sociale uitsluiting.

Bereikbaarheidsarmoede index

Om het risico op bereikbaarheidsarmoede te beperken, zullen we empirisch moeten vaststellen welke gebieden en mensen een bereikbaarheidsniveau hebben beneden de bereikbaarheidsarmoedegrens. Hoewel de belangstelling voor het meten van bereikbaarheidsniveaus toeneemt, is er nog geen index ontwikkeld om systematisch de omvang en reikwijdte van bereikbaarheidarmoede – als één van de meest fundamentele bereikbaarheidsproblemen – te beoordelen.

Op basis van de door Foster et al. (1984) voorgestelde index om inkomensarmoede te meten, ontwikkelen we in deze paper een bereikbaarheidsarmoede index, die rekening houdt met zowel de intensiteit van de bereikbaarheidsarmoede (hoe laag is het algemene bereikbaarheidsniveau ervaren door een persoon?) als de omvang van de bereikbaarheidsarmoede (hoeveel mensen worden getroffen door bereikbaarheidsarmoede?). We definiëren bereikbaarheidsarmoede (AP) als:

$$AP = \frac{1}{N}\sum_{i=1}^{H}\left(\frac{z-y_i}{z}\right)^2$$

Hierin staat *N* voor de totale bevolking; *H* is het aantal personen met ervaren bereikbaarheidsniveaus beneden de bereikbaarheidsarmoedegrens *z;* en y_i is het bereikbaarheidsniveau ervaren door de i-de groep beneden de bereikbaarheidsarmoedegrens *z*.

Amsterdam

We hebben de index toegepast om het risico op bereikbaarheidsarmoede in de regio Amsterdam te boordelen. Wellicht tegen de verwachtingen in, zien we dat niet de rurale maar juist de urbane en suburbane gebieden het meest bijdragen aan het algehele risico op bereikbaarheidsarmoede in de regio. Dit wordt veroorzaakt door de concentratie van (autoloze) huishoudens met lage inkomens in deze (sub)urbane gebieden, in combinatie met inadequate vervoersdiensten. In landelijke gebied is de bereikbaarheid weliswaar een stuk lager, maar het aantal mensen dat daarvan de consequenties ondervindt is zeer beperkt. De resultaten van de analyse suggereren dan ook dat investeringen in het (openbaar) vervoersysteem zich op de geïdentificeerde (sub)urbane gebieden moeten richten.

1. INTRODUCTION

Over the past decades, the need to travel has increased as societies became organized around motorized transport, and especially the car. Ever since, researchers have been concerned about the possible consequences for people that are unable to drive a car for legal, financial or physical reasons (e.g. (Schaeffer and Sclar 1975)). From the end of the 1990s, this debate has been linked to the role of transport in the process of social exclusion (e.g. (Lucas 2012)), based on the understanding that accessibility problems can be both a cause for, and a result of, social exclusion ((Farrington and Farrington 2005)). Over the past ten years, a substantial body of evidence has developed, providing a largely qualitative understanding of transport poverty in a number of Western countries. This body of research suggests that a substantial share of the population experiences some problems to access key destinations, such as employment, health care facilities and education ((Lucas 2012)).

While the interest in the disparities in accessibility is on the rise, no index has been developed yet to systematically assess the size and scope of the accessibility problems people may experience in a particular area. The development of such an index is important, as it would allow a systematic analysis of possible accessibility problems across a region, as well as a systematic comparison across regions. The aim of this paper is to develop such an index and apply it, as a first exercise, to one urban region in the Netherlands.

The paper is organized as follows. Following this introduction, we first discuss some philosophical underpinnings for our index (Sections 2 and 3). This results in the definition of the accessibility poverty. We then turn to the literature on income poverty measurement (Section 4), to draw inspiration for the development of an accessibility poverty index, which we present in Section 5. Following a brief description of our data for the Amsterdam region (Section 6), we present the results in Section 7. We end with a brief conclusion.

2. A FAIR DISTRIBUTION OF ACCESSIBILITY

Our argument starts from one of the main goals of transportation policy: the improvement of people's ability to travel from one place to another in order to enable participation in out-of-home activities (cf. Martens 2011; Martens 2014). Government interventions in the transportation domain (e.g. investments in infrastructure, provision of services or public transport subsidies) focus on the former: they aim to improve people's ability to travel, i.e. their potential mobility, understood as the ease with which a person can move through space (e.g., Sager 2005). By doing so, these interventions improve people's accessibility and thus people's ability to engage in out-of-home activities (subject to the ceteris paribus condition). From the perspective of fairness, potential mobility itself is of limited importance. It is the ability to participate in activities that is more closely related to people's well-being. In terms of philosophies of social justice: the ability to participate in activities, as measured in terms of accessibility, is the focal variable (Sen 1992). It is the 'space' within which fairness is to be obtained. The fairness of government interventions in the transport system thus depends on the extent to which these interventions contribute to a fair distribution of the ability to participate in activities. Note that actual activity participation is merely an indicator of the extent to which a transportation system provides sufficient accessibility for all to participate in activities. This is so, because accessibility captures only the potential-to-participate. Whether people actually make use of this potential and engage in out-of-home activities obviously depends on more factors than accessibility itself alone, including lifestyle and personal preferences. Thus, low activity participation does not necessarily point at a low level of accessibility.

What might be a fair distribution of accessibility? In order to address this complex question, we turn to the relation between accessibility and actual activity participation. The starting point for the argument is the observation that under normal circumstances, a society's dominant mode of transport provides an acceptable level of accessibility for all those that have access to that transport mode. Land use patterns are shaped by transport networks and tend to organize around the speed provided by the dominant transportation mode, i.e. the mode used by the majority of the population. In societies before the industrial revolution, walking was the dominant mode. With the rise of the automobile, land uses started to organize around the speed provided by the car, a process which is still ongoing in many countries. Persons with access to a motorcar have no problem navigating these land use patterns – the motorcar provides them with sufficient accessibility. However, because of the reorganization of land uses following the ascent of the car, motorized transport rapidly turned from a luxury into a necessity. Few people in industrialized societies are now able to manage their daily lives without, individualized or collective, motorized transport (Urry 2004).

In motorized societies, patterns of accessibility are shaped by two structuring dimensions (Martens 2012): mode availability and space. In terms of mode availability, persons with access to the dominant mode of transport (read: the car-road system) will face few accessibility problems in current societies. Whether persons without access to a car, due to legal, financial or physical barriers, will experience insufficient levels of accessibility depends on the accessibility provided by alternative modes of transport (in modern societies, typically the public transport system). In terms of space, place of residence has a strong impact on a person's accessibility levels, because of the inevitable existence of centers and peripheries (Puu 2005). It may be clear that persons residing close to centers of employment and services will experience substantially higher accessibility levels, than persons residing in suburban or ex-urban locations.

The fact that space creates, by its very nature, center and periphery implies that accessibility can never be distributed in an equal way over population groups. This implies that the search for a fair distribution of accessibility has to deliver an alternative distributive rule from equal distribution. In order to develop this distributive rule, or fairness principle, we first define the relevant population groups over whom accessibility is 'distributed'. As mentioned above, both mode availability and space strongly shape a person's accessibility level. The analysis of the distribution of accessibility thus has to focus on population groups that differ in terms of mode availability and residential location. In terms of mode availability, it is reasonable to make a distinction between persons with access to a car and persons who lack such access and are primarily confined to the public transport system in conjunction with walking. This distinction does not capture the full variety in terms of the available modal set observed among persons (as some may also be able to use a bicycle in addition to public transport and walking, while others may be able to use a moped in addition to public transport and walking, and yet others may be able to use all these transport modes), but it does address the most important distinction in current modern societies and probably captures the groups with the largest differences in accessibility levels. In terms of space, it is reasonable to make a distinction between persons in terms of residential location, for instance at the level of a neighborhood, a six-digit postal code, or a transport activity zone, depending on available data, as the residential location serves as the 'hub' from which persons organize their daily life. These two characteristics lead to a distinction of population groups by mode availability and location. These groups will differ in terms of their accessibility. The question we need to answer is: which distribution of accessibility over these groups is fair?

In order to make the next step in our analysis, we return to the relationship between accessibility levels and activity participation. It may be hypothesized that the level of accessibility and the intensity of activity participation are correlated. All else being equal, it may be assumed that with increasing levels of accessibility, a person's level of participation in out-of-home activities will go up. The relation will be a concave one, as the impact of one unit of additional accessibility in a situation of high accessibility will have little influence on activity participation. Furthermore, it may be assumed that there is no strict relation between accessibility levels and activity participation intensity, as people highly differ in their need or desire to participate in out-of-home activities. For a given level of accessibility, we may thus well observe persons with high and low intensities of activity participation.

As the accessibility provided by the transportation mode available to a person (as a representative of a particular population group distinguished in terms of mode and residential location) decreases, we may expect a drop in the level of actual activity participation. It could be argued that this drop is unproblematic as long as it has no severe impacts on the quality of a person's life. Part of the decrease may actually be a representation of preferences: people who have less desire to carry out out-of-home activities may well prefer less accessible residential locations in ex-urban settings over highly accessible urban locations. But when accessibility levels drop even further, the transport system may actually create a barrier for people to obtain a job, obtain health services, participate in education, or keep in contact with friends and family. This situation is referred to in the literature as transport-related social exclusion and occurs if *systematic* problems of accessibility to opportunities lead to significant *impacts* on a person's life, such as unemployment, deterioration of health, or social isolation (e.g., Kenyon, Lyons et al. 2002; Farrington and Farrington 2005; Lucas 2012; Martens 2013).

The relationship between accessibility and activity participation is depicted in Figure 1. Each point in the figure represents a person with a particular residential location (e.g., by neighborhood) and set of available transport modes. Note that many persons may experience roughly comparable levels of accessibility, as they are virtual identical in terms of residential location and mode availability. At high levels of accessibility, there will be substantial variation in activity participation, depending on people's preferences and other factors. However, with decreasing accessibility, the relation between accessibility level and activity participation will grow in strength. At a certain point, it can be hypothesized, accessibility levels are so low, that they directly limit a person's possibility to participate in activities. When this occurs, people experience what is referred to in the literature as 'transport poverty' or 'transport-related social exclusion': the accessibility level has decreased to such an extent that people are no longer able to fully participate in the activities deemed normal for society. Empirically, it will not be easy to exactly draw this 'accessibility poverty line' (Martens 2014). Conceptually, however, it is possible to define it.

A fair transport system, then, is a system that provides every citizen with a sufficient level of accessibility to participate in activities deemed normal to society (cf. the social exclusion literature). From a fairness perspective, transport policies should first and foremost address the accessibility needs of people who fall below the accessibility poverty line (see for a more elaborate discussion, Martens 2013). Some deviations from this principle may be acceptable, notably if the size of the community experiencing an insufficient accessibility level is small and the costs of improving the community's accessibility, which has to be carried by the entire community, is disproportionally high. In contrast, deviations from the fairness principle based on the notions of responsibility and choice – i.e., households may have deliberately chosen a residential location with a low accessibility level – are highly undesirable, as ascribing personal responsibility is extremely difficult (cf. Daniels 2008, p. 76-77). It assumes that households are truly free in their selection of a residential location and thus assumes that the housing market provides a sufficient range of options for all types of households, irrespective of e.g. income, households size, or ethnicity. The large body of literature on housing markets show that this rarely is the case (cf. Harvey 1973), even in countries with substantial government intervention in the housing market. The emphasis on choice and personal responsibility also ignores the constitutive interests people may have in a particular house, in which they may have lived their entire life, or in a particular place, in which most of their social life may take place (Dagan 2014). Both these lines of argumentation obviously are in need of further elaboration, but we will leave this to another occasion.

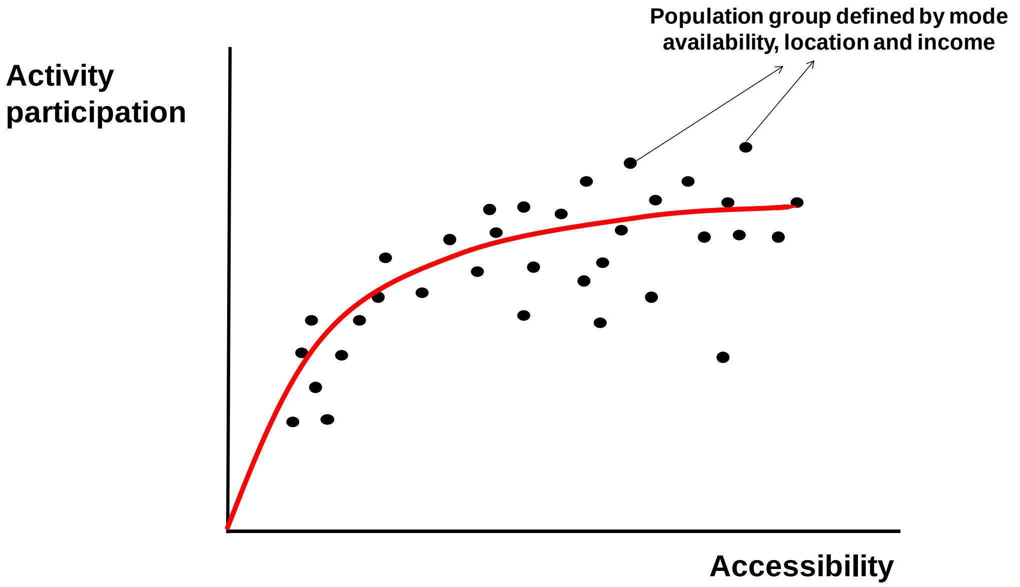

FIGURE 1 Schematic representation of the relationship between accessibility and activity participation

3. ACCESSIBILITY POVERTY AND ACCESSIBILITY POVERTY RISK

The argument developed above underscores the relationship between accessibility and activity participation, but also acknowledges that this relationship has a rather loose character. High accessibility levels will enable a range of levels of activity participation, while that range will contract with a decrease in accessibility level. Yet, even with low levels of accessibility, a person may well have a rich level of activity participation, because she has been able to arrange her life around the limited set of transportation options available to her. So low levels of accessibility are only an indication that accessibility poverty *may* occur in a particular area. Yet, we argue that the measurement of accessibility levels is preferable over the measurement of 'participation' poverty per se, most importantly because people have a fundamental interest to protect the range of options open to them (Rawls 1971; see also Sen 2011 [1980]), even if they manage well with a sub-standard general level of accessibility for a period of time. Since a sufficient level of activity participation at a particular moment in time does not guarantee that a person will be able to carry out a normal range of activities as her plans, or the circumstances, change over time, it is important to focus on accessibility rather than activity participation.

Taken together, these arguments suggest that accessibility measurement must always capture a 'general' notion of accessibility and abstract from the actual trips made by persons and even, at least in the first instance, of the characteristics of the person. The general measure of accessibility will only be an *indication* of the possible extent of participation poverty a person experiences. Hence, the index to be developed is an index of accessibility poverty *risk*. The lower the *general level* of accessibility, the higher the chances that a person will experience a low *personal* level of accessibility, the higher the chances that the person will not be able to participate in a reasonable set of activities, and the higher the chances of accessibility poverty.

In order to develop the index of accessibility poverty risk, we turn to the literature on the measurement of income poverty.

4. INDICES FOR INCOME POVERTY (RISK)

A substantial body of literature has been published on the measurement of income poverty, which emerged from the need to compare poverty levels across cities and regions and assess policy initiatives on the poor (Foster, Greer et al. 1984; Ravallion 1992). Income poverty relates to inadequately low income and is generally seen as one of the crucial aspects of economic deprivation (Foster and Sen 2008 [1997]). In order to measure and compare levels of income poverty within and between communities, the poor must first be identified among the total population. This implies that a minimum income must be determined below which people are counted as poor, i.e. an 'income poverty line' has to be fixed. Subsequently, various ways can be distinguished to determine the level of income poverty in a community.

A commonly used measure of poverty is the *head-count ratio*, which identifies the ratio of the total population with incomes below the poverty line. With a number of q people with income less than or equal to the poverty line z within a total population of n people, the head-count ratio is defined by:

$$H = q/n$$

The head-count ratio provides insight into how widespread poverty is across a population, but ignores the 'depth' and distribution of poverty as all poor are counted the same. As a result, it is not possible to assess which person(s) are worst off in a community and to whom policy initiatives should focus on. In order to determine where poverty is most severe, also actual income levels of the poor must be taken into account (Foster and Sen, 1997).

This 'depth' of poverty can be measured by the shortfall of poor people's incomes relative to the poverty line, i.e. the extent of the 'gap' between a poor person's income and the poverty line. Subsequently, the overall shortfall of the incomes of the poor can be captured by the use of a so-called aggregate gap-measure. The *income-gap ratio* reflects the average shortfall of the incomes of the poor μ_p expressed as a share of the poverty line z, with the least poor having incomes no greater than the poverty line:

$$I = (z - \mu_p)/z$$

The gap-measure will provide an indication of the 'depth' of poverty among the poor. However, like the head-count ratio, it may not adequately capture the severity of poverty as it ignores the differences in income shortfalls of the poor. For instance, when a transfer of income takes place from a poor person to a less poor person, whose income remains below the poverty line after the transfer, then neither the income-gap ratio nor the head-count ratio would show any change in the levels of poverty across the population.

The limitations of both the head-count ratio and the income-gap ratio led to the proposal of distribution-sensitive poverty measures (Foster and Sen, 1997). A well-known poverty measure proposed by Sen (Sen 1973) incorporates both previously discussed measures as well as a measure of income distribution among the poor, by including the Gini coefficient G_p. The Gini coefficient registers regressive transfers of income between the poor, by giving more weight to the income shortfall of the poorest among the poor. The weights are fixed by the ranked 'relative distribution' of incomes, whereby the weight ascribed to a poor person increases the more the person is positioned at the bottom of the income distribution among the poor. The *S measure* combines the head-count measure H and the income-gap ratio I and is defined by:

$$S = HI + H(1-I)G_p$$

Since the S measure, and various extensions and modifications, have been widely discussed in the literature (see for instance Foster et al., 1984), we will only focus on some important aspects of this particular measure. The S measure satisfies the properties of *monotonicity* and the *focus axiom*, as it ensures that any decrease in income of the poor increases the overall poverty level, while being invariant with respect to the non-poor since it focuses specifically on the poor. It also satisfies the *weak* *transfer condition*, which requires that a transfer of income from a poor person to a richer poor person must result in an increase of overall poverty. However, this result is not clear when the transfer of income makes the recipient cross the poverty line, due to the importance that is attached by the S measure to the head-count ratio. Therefore, it fails to satisfy the *strong transfer condition* (Foster and Sen, 1997). In addition, the S measure does not comply with *subgroup consistency* as well as *decomposability*, which requires that subgroup poverty levels aggregate to overall poverty and, hence, that the aggregate poverty level decreases when a subgroup's poverty level is reduced.

A class of poverty measures which are specifically designed to satisfy the aforementioned properties, are the P_α measures. The parameter α is perceived as an indicator of the contribution of inequality among the poor in assessing poverty. We confine ourselves to the case where $\alpha = 2$, the so-called P_2 measure proposed by Foster et al. (1984), since this measure has the clearest structure of all. In contrast to the S measure, whereby the weight on an individual's income shortfall depends on the income shortfalls of others, the P_2 measure takes the weight of an individual's income shortfall to be the income shortfall itself. As a result, the P_2 measure is totally *decomposable* and *subgroup consistent*, since the overall poverty level of a community can be seen as the (weighted) sum of the subgroup poverty levels, with weights given by the ratio of the population of a subgroup to the total population of the community (Foster et al., 1984; Ravallion, 1992). With *q* number of subgroups with incomes no greater than the poverty line *z* in a total population *N*, and y_i representing the income of the *i*th subgroup, than the P_2 measure is expressed by:

$$P_2 = \frac{1}{N}\sum_{i=1}^{H}\left(\frac{z-y_i}{z}\right)^2$$

The value of P_2 ranges from 0 to 1, with a score of 0 indicating the case of an entire population with an income level above the poverty line, and a score of 1 the case of an entire population below the poverty line. The decomposability of the P_2 measure allows the breakdown of the overall poverty level into components, making it possible to determine the extent to which an increase or decrease in the poverty level of a subgroup contributes to the overall poverty level. The subgroup poverty levels represent the average poverty level of the population of the respective group, as each person is given the average shortfall of that group. The poverty line, when fixed, is taken as the standard against which all subgroup incomes are compared, and is taken to be constant across all subgroups. In order to determine the contribution of a subgroup to overall poverty, the subgroup poverty level is weighed by its population share and then expressed as a percentage of overall poverty, which, when contributions of all subgroups are summed, add up to exactly 100% (Foster et al., 1984; Foster and Sen, 1997). By eliminating poverty in a subgroup, the overall poverty level will decrease exactly by the subgroup's rate.

The P_2 measure can be used to develop a measure to assess and compare accessibility poverty across an area. Because of its decomposability, the measure can also be employed to assess the extent of accessibility poverty risk experienced by various groups in the population. Hence, in the following, we develop our index of accessibility poverty risk based on the P_2 measure.

5. AN INDEX OF ACCESSIBILITY POVERTY RISK

As we have argued, the ultimate goal of a fair transport system would be to provide all people with a sufficient *general* level of accessibility to participate in activities deemed normal in society. This general accessibility level gives an indication of the personal level of accessibility and, hence, the possible extent of accessibility poverty a person experiences. Population groups will differ in terms of their accessibility levels, due to differences in mode availability and residential location. In terms of mode availability, we distinguish between the levels of accessibility provided by the (dominant) car-road system and the public transport system, since cars in today's societies tend to provide substantially higher levels of accessibility then public transport, while access to a car may be limited due to legal, financial or physical reasons. In terms of residential location, the level of accessibility is a function of both the transportation system and the spatial distribution of activities, with people residing in high density areas and/or well-connected to the transport system typically experiencing relatively high accessibility levels.

It follows that in order to evaluate the levels of accessibility poverty risk across an area we need to empirically assess which population groups have insufficient levels of accessibility, i.e. which groups have an accessibility level below the 'accessibility poverty line'. If the accessibility poverty line is drawn at the proper level, persons with insufficient accessibility levels are likely to experience (severe) accessibility problems and, hence, structural accessibility poverty. In order to do so, we need to assess a person's mode availability as well as residential location. For residential location, use can be mode of postal code areas, census tracts, neighborhoods or transport activity zones, depending on the available data. The situation is somewhat more complex regarding mode-availability. While it would seem obvious to assume that people who own a car can make use of the road system and thus benefit from the car-based accessibility provided by that system, this approach has some flaws from the perspective of poverty measurement, since there may be a certain degree of forced car ownership, due to spatial dispersion of out-of-home activities or a lack of public transport. In addition, people with low incomes could own a car for particular trips only, while making little use of it in everyday life due to the relatively high costs of car use. Therefore, the level of income is a more appropriate indicator, since it strongly correlates with access to transport, and more specifically with access to a car. In what follows, we assume that poor households are dependent on the cheaper mode of transport (i.e., public transport), while all other households are assumed to be able to secure access to car-based mobility (which may be obtained through car-sharing services). Obviously, this is a gross simplification of the situation, as some lower income households may well have sufficient income to own and operate a car (e.g., because of low residential costs), while some higher income groups may lack the means to purchase a car (e.g., because of households size or dependent children pursuing (expensive) higher education). We maintain, however, that this approach provides a better proxy of accessibility poverty than a differentiation of households based on car ownership, for the reason given above. Note that accessibility poverty may be experienced by all income groups, even though the four highest income quintiles are assumed to have access to a car and therefore enjoy the typically higher accessibility level enabled by the car in current societies. We will return to this later.

In line with Foster et al. (1984) we can then have define accessibility poverty (AP) as:

$$\text{AP} = \frac{1}{N}\sum_{i=1}^{H}\left(\frac{z-y_i}{z}\right)^2$$

where *N* represents the total population; *H* the number persons experiencing accessibility levels below the accessibility poverty line *z*; and y_i the accessibility level experienced by the i-th group below the accessibility poverty line *z*.

The positioning of the accessibility poverty line *z* is clearly not a straightforward matter, as the relationship between (low) accessibility levels and activity participation has not been systematically studied (in contrast to the link between income levels and income poverty). Ravallion (1992) provides a broad overview of possibilities to set the poverty line for the case of income. We will not explore the parallels here for the case of accessibility poverty. Generally, a proper setting of the accessibility poverty line would require a deeper understanding of the relationship between general accessibility levels and out-of-home activity participation. Lacking data on this relationship, we have adopted here a mathematical approach to set the poverty line, which is also common in the domain of income poverty. It starts by calculating the (weighted) average of the levels of accessibility experienced by (car-owning and car-less) households in an entire region. Obviously, the average level of accessibility cannot serve as the accessibility poverty line, as it would imply that accessibility poverty can never be eradicated, no matter how efficient the transport (and land use) system, as some people will always experience an accessibility level below the average. Yet, it may also be clear that households experiencing a substantial negative deviation from the average accessibility level, are more prone to face accessibility poverty. Hence, the accessibility poverty line could be defined as a particular percentage of the average accessibility level (e.g., 40% or 60% of the average (or median) accessibility level). This approach obviously has its limitations. First, it results in an arbitrary determination of the accessibility poverty line. This pitfall can be avoided by analyzing accessibility poverty for a variety of poverty lines. Second, since the poverty line will depend on the area of study, it may result in an under-estimation of accessibility poverty if accessibility levels are relatively poor across the board, e.g. due to extreme forms of congestion resulting from e.g. a rapid population growth outpacing investments in transport services and infrastructure. The advantage of this approach lies in the fact that a differentiation in poverty lines across metropolitan regions or countries is in line with the century-old observation that poverty is not an absolute, but a relative phenomenon: basic needs tend to expand with the increase in affluence in a society, shifting the poverty line upwards (see e.g. (Sen 1983)). This may hold even stronger in relation to accessibility, as the accessibility experienced by the majority of the population tends to shape land use patterns, requiring higher minimum levels of accessibility for full participation in society. Differentiation in the accessibility poverty line is thus acceptable, although it may call for additional analysis, and scrutiny of the underlying datasets, for different localities.

In what follows, we will use the mathematical approach for setting the accessibility poverty line and we present the results for four poverty lines: 20%, 40%, 60% and 80% of the average accessibility level. We apply the index to analyze accessibility poverty in the Amsterdam metropolitan area in the Netherlands.

6. DATA AND CALCULATIONS

Our study encompasses the Amsterdam metropolitan region, situated in the Randstad, the main economic area of the Netherlands, in the west of the country. In 2009, the Amsterdam region had 1,387,640 residents, of which 204,740 residents (14.8% of the total population) belong to the lowest income quintile (CBS, 2013).

In order to evaluate the levels of accessibility poverty risk in both regions, we have assessed which population groups experience insufficient levels of job accessibility. We have carried out this analysis at the level of four-digit postal code areas. The Amsterdam region includes a total of 189 four-digit postal code areas. For each postal code area, data are available on the total population, the population belonging to the lowest income quintile, the urbanization level, and the number of jobs accessible by car or public transport within a 30 minutes travel time threshold. Data on the population and urbanization level are obtained from the Dutch Bureau of Statistics (CBS, 2013). CBS defines urbanization level as the number of addresses per square kilometer and distinguishes between five categories of urbanization (from 'very highly urbanized' to 'not urbanized'). Data on accessibility by car and public transport in morning peak hours were provided by the Dutch consultancy Goudappel Coffeng. Based on the accessibility levels of the 189 zones, we determined the weighted average accessibility level for the entire region. As may be expected, and in spite of a relatively well-developed public transport system, the average accessibility by car is substantially higher than by public transport (717,892 versus 199,784 jobs), resulting in an average weighted accessibility of 458,837 jobs. Subsequently we have defined the accessibility poverty lines as 20%, 40%, 60% and 80% of this regional average accessibility level. Note that we did not weight the average accessibility based on the observed modal split for the region or on the share of the population which we consider as transit dependent (the lowest income quintile only).

Such weighting would obviously have led to a much higher average accessibility level for the entire region and, thus, to higher accessibility poverty lines.

Obviously, the data have been collected for other purposes and so the findings below should be interpreted with care. Most importantly, our analysis may suffer substantially from the Modifiable Area Unit Problem (MAUP), i.e. a different spatial scale of analysis may well result in different results. This is especially true, as the measurement of public transport accessibility at the level of (large) zones is known to be problematic (e.g., (Benenson, Martens et al. 2011)).

TABLE 1 Accessibility poverty in Amsterdam region, for four poverty lines.

Poverty line	Zones		Population		Population in lowest income quintile		Average weighted accessibility (# jobs)	P2 value	Share of population below accessibility poverty line
	Abs.	%	Abs.	%	Abs.	%			
80%	172	91.0	1.227,310	88.4	165.001	80.6	173.935	0.029	11.9%
60%	147	77.8	1.004,920	72.4	118.919	58.1	144.175	0.020	8.6%
40%	99	52.4	545.260	39.3	47.403	23.2	66.627	0.014	3.4%
20%	72	38.1	353.790	25.5	27.507	13.4	34.249	0.008	2.0%

7. RESULTS

Below, we describe how the pattern of accessibility poverty risk changes, in terms of size as well as spatial pattern, with a change in the accessibility poverty line. Note that we have only included the accessibility poverty experienced by the lowest income quintile, who is assumed to be transit-dependent. Depending on the poverty line, some zones experience insufficient levels of car-based accessibility. In some but not all cases, this is compensated for by sufficient levels of public transport accessibility. We exclude this form of accessibility poverty, as in most cases the poverty is not caused by a poor transport system, but rather by a low density of employment within the 30 minutes travel time catchment area of these zones.

The results show, first of all, that accessibility poverty is relatively limited in the Amsterdam region (Table 1). The P_2 score increases from 0.008 for the 20% poverty line to 0.029 for the 80% poverty line (recall that a P_2-score of 0 implies that the entire population is above the poverty line, while a score of 1 that the entire population is below the poverty line). Obviously, the P_2 value is expected to be relatively limited, as the vast majority of the four highest income quintiles is assumed to own and operate a car and to experience (car-based) accessibility levels well above the accessibility poverty lines. The scores should therefore not be interpreted in isolation, but should be used to compare the relative position of regions vis-à-vis each other. We aim to take up that challenge in a future paper.

Second, it may be clear that the share of the population experiencing an accessibility level below the poverty line decreases with a decrease in the height of the poverty line (Table 1). For the 80% poverty line, 80.6% of the low-income population has insufficient accessibility by public transport. This share drops to only 13.4% for the 20% poverty line. For each poverty line, the percentage of the total poor population living below the poverty line is lower than the percentage of the total population. This indicates that the low income groups live in areas with a higher public transport accessibility levels than the average person. This difference increases as the poverty line drops: where 13% of the population below the 80%-poverty line belongs to the lowest income quintile, this percentage drops to 8% for the 20%-line. This finding may the results of various processes, such as the residential choice behavior of low income groups, affordable housing policies, or public transport investment priorities, or all of these together.

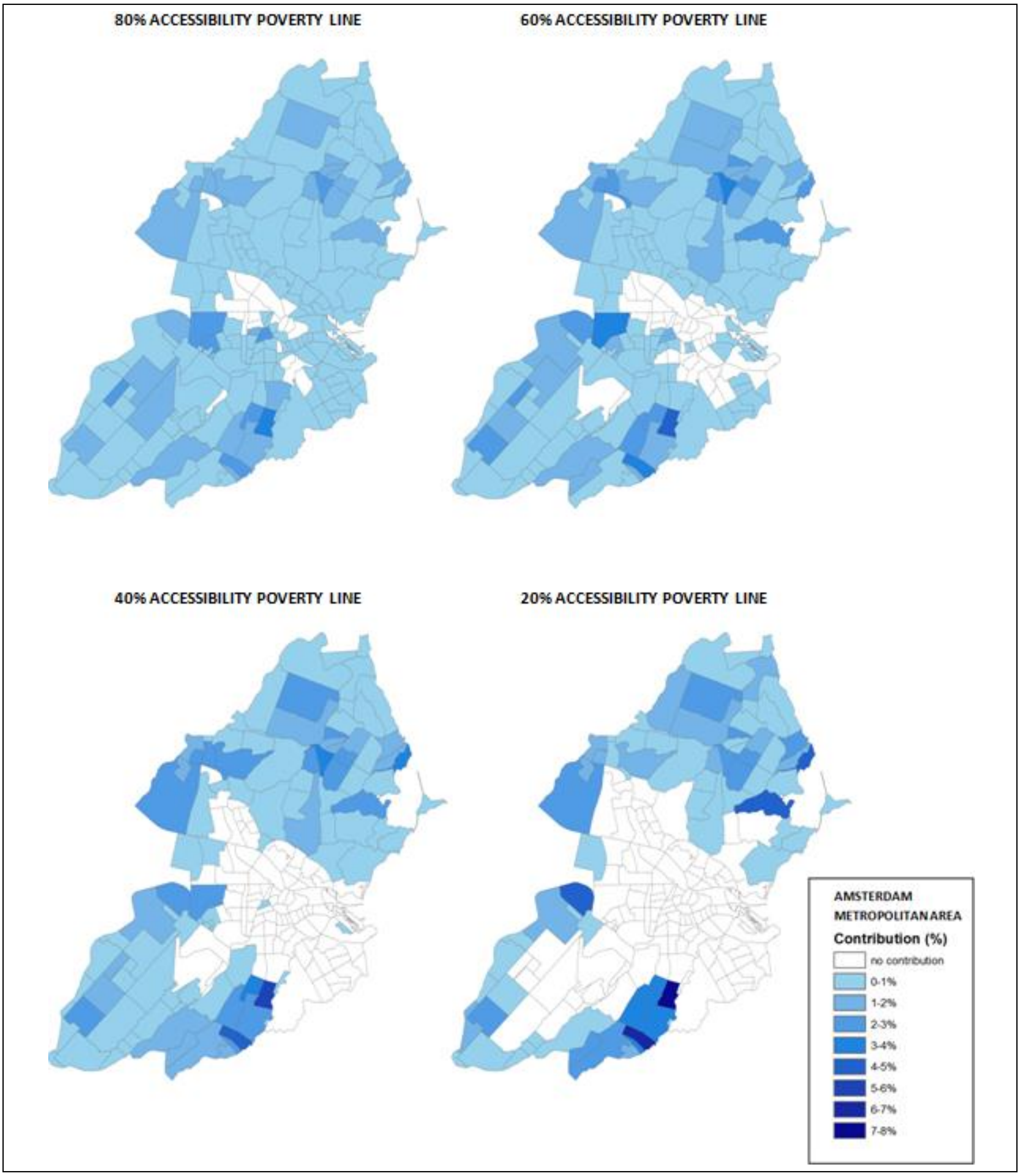

FIGURE 2 The changing spatial pattern of accessibility poverty risk in response to a decrease in the accessibility poverty line from 80% to 20%.

Third, the spatial pattern of accessibility poverty risk changes fundamentally with a decrease in the poverty line. For the 80%-line, only a limited number of zones directly in and around the city center of Amsterdam have a sufficient level of accessibility (17 zones, i.e. 9% of all zones in the region). These zones obviously benefit from the high quality of the public transport system in the urban core, as well as from the proximity to jobs in both the city center and the concentration of offices in the south of the city. The small core of areas enjoying a sufficient level of public transport accessibility expands, in a nearly exemplary way, outward with each drop in the poverty line (Figure 2). Note that this pattern emerges in spite of the fact that all jobs around a zone are taken into account in measuring (public transport) accessibility. That is, the zones on the periphery do not have a low level of accessibility because of their peripheral location vis-à-vis the concentration of jobs in Amsterdam. Actually, the zones in the south of the region are located relatively close to the city of Utrecht as well as the international airport of Amsterdam, which both are concentrations of employment. Apparently, the relative proximity to these centers does not translate into substantial job accessibility by public transport, possibly because of the historic structure of the public transport system, and possibly because of the relatively low travel time threshold we have used (30 minutes). Additional analyses could show if this spatial pattern of accessibility poverty risk holds for higher travel time thresholds.

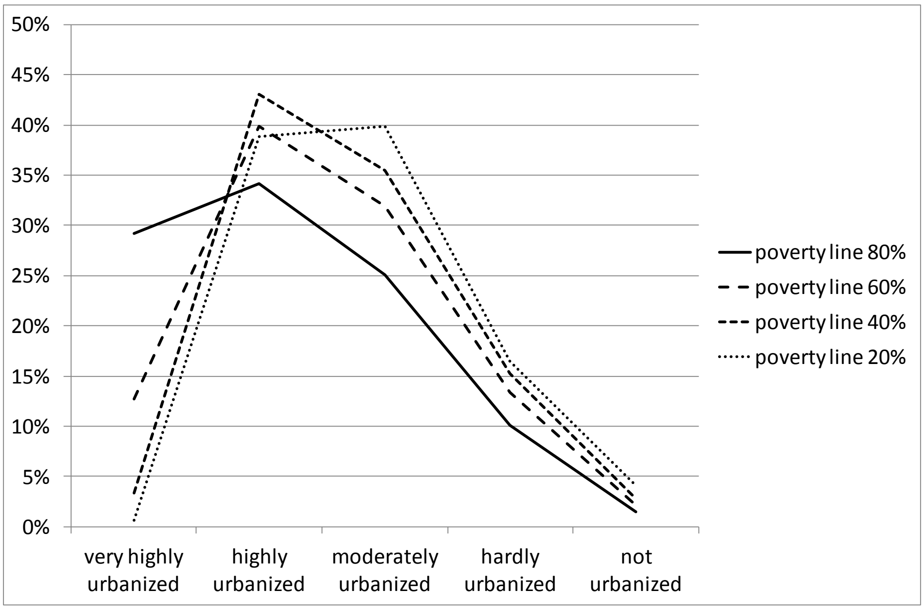

FIGURE 3 Change in the contribution of the five levels of urbanization to total accessibility poverty in the Amsterdam region.

The analysis of the spatial pattern suggests that accessibility poverty retreats to rural areas with a decrease in the accessibility poverty line. This impression is misleading, however. An additional analysis by urbanization level shows that accessibility poverty risk remains a primarily (sub)urban phenomenon in the Amsterdam region. To understand this, we have arranged all zones by urbanization level and analyzed the contribution of each group of zones to the overall accessibility poverty of the region. This analysis results in the percentage each group is contributing to overall accessibility poverty, with the total summing up to 100%. As discussed above, the P_2-index enables this analysis, which is one reason for adopting this measure. The results are shown in Figure 3. The figure shows that the contribution of the 'very highly urbanized' zones drops rapidly with a decrease in the accessibility poverty line, but the overall contribution of the 'highly urbanized' zones actually increases with a drop in the poverty line. Only for the lowest 20%-line, the relative share of the 'highly urbanized' zones decreases somewhat in favor of the 'moderately urbanized' zones. The contribution of the 'hardly urbanized' and 'not urbanized' zones remains low, irrespective of the poverty line. This is obviously the consequence of the small size of the population in these two types of zones. Thus, while the accessibility shortfall is most substantial in these zones, the number of people affected by this extreme form of accessibility poverty is limited.

This analysis is confirmed if we analyze the ten areas with the highest contribution to overall accessibility poverty in the Amsterdam region (see Table 2 at the end of the paper). This 'top-ten' mainly consists of 'highly urbanized' and 'moderately urbanized' zones and hardly changes with a decrease in the poverty line. This underlines again that the number of people affected by a poor accessibility level is relatively important for understanding the phenomenon of accessibility poverty risk. This is not a weakness of the P_2 index, but rather a strength. After all, if the accessibility poverty line is set with care, then it may be assumed that persons experiencing any negative deviation from that poverty line may actually be at risk of accessibility poverty, i.e. may experience serious barriers to participate in out-of-home activities. Clearly, these deviations become all the more important, the more people are affected by it.

7. CONCLUSION

While the interest in accessibility disparities is on the rise, no index has been developed yet to systematically assess the size and scope of accessibility problems across and between regions. The aim of this paper was to develop such an index and apply it, as a first exercise, to one urban region in the Netherlands. We have started with the definition of accessibility poverty, which refers to a situation of low accessibility that severely restricts a person's ability to participate in the activities deemed normal in a particular society. A person is exposed to accessibility poverty *risk* when he lives in an area with a low *general* level of accessibility. Drawing on the indices to measure income poverty, we have defined an accessibility poverty risk index, which takes into account both the intensity of accessibility poverty (how low is the general accessibility level experienced by a person?) and the extent of accessibility poverty (how many people are affected by accessibility poverty?). We have applied the index to assess accessibility poverty risk in the Amsterdam region. Perhaps against expectations, we find that (sub)urban areas contribute most to the overall accessibility poverty risk in the region. This is explained by the sheer size of the (poor) population in these areas. Thus, while rural areas may experience the most 'intense' form of accessibility poverty, the extent of accessibility poverty is actually strongest in suburban areas.

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