Transport Planning With Accessibility Indices in the Netherlands

Discussion Paper

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International Transport Forum

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Cite this work as: Geurs, K.T. (2018), "Transport Planning With Accessibility Indices in the Netherlands", Discussion Paper, International Transport Forum, Paris.

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1. Introduction

Accessibility has been central to physical planning and spatial modelling for more than fifty years. The concept of accessibility, as it accounts for both the pattern of activities and for the links between activities provides a basis for making trade-offs between land-use and transportation policies. As a measure of the potential for interaction of one place and persons to all other places or persons, conceptually linked to Newton's law of gravity, accessibility's origins can be traced back to the 1920s when it was used in location theory and regional economic planning (Batty, 2009). In his classic paper "How Accessibility Shapes Land Use", Hansen (1959) was the first to define accessibility as a potential of opportunities for interaction; he applied the concept to forecast employment development in Washington D.C. A plethora of accessibility definitions and operationalisations of accessibility measures has been developed in the past decades and applied in several academic fields such as urban geography, rural geography, health geography, time geography, spatial economics and transport engineering. In the past decade it seems that accessibility research is flourishing due to a growing abundance of spatial data.

This discussion paper overviews the different perspectives and approaches to measuring accessibility, reviews the strengths and weaknesses of different accessibility indicators, and describes the use of accessibility indicators in the Dutch policy and planning practice.

The rest of the paper is structured as follows. Section 2 describes different components of accessibility. Section 3 provides a brief review of accessibility measures. Section 4 describes the Dutch practice of applying accessibility indicators in Dutch transport policy and planning, and its limitations and finally, Section 5 presents the conclusions and discussion.

2. The components of accessibility: Overview and progress

Many different applications have been developed in these fields and can be categorised in several ways. Here, we use the categorisation of accessibility measures from the review paper from Geurs and Van Wee (2004). With over 500 citations in Scopus and over 1 200 citations in Google Scholar, for a decade many accessibility papers have used the framework provided in this paper. They provided an overview of components of accessibility, distinguishing four main components.

The land-use component reflects the land-use system, consisting of (a) the amount, quality and spatial distribution of opportunities supplied at each destination (jobs, shops, health, social and recreational facilities, etc.), (b) the demand for these opportunities at origin locations (e.g. where inhabitants live), (c) the confrontation of supply of and demand for opportunities, which may result in competition for activities with restricted capacity such as job and school vacancies and hospital beds. With advances in geospatial technology, internet technology and growing abundance of detailed spatial data, accessibility researchers have developed indicators at a high spatial resolution, as well as web-based mapping and applications that use internet technologies to retrieve detailed information about local amenities (e.g., Páez et al., 2013).

The transportation component describes the transport system, expressed as the disutility for an individual to cover the distance between an origin and a destination using a specific transport mode; included are the amount of time (travel, waiting and parking), costs (fixed and variable) and effort (including reliability, level of comfort, accident risk, etc.). This disutility results from the confrontation between supply and demand. The supply of infrastructure includes its location and characteristics (e.g. maximum travel speed, number of lanes, public transport timetables, travel costs). Several researchers have focused on a detailed treatment of transport impedance factors to improve accessibility estimations.

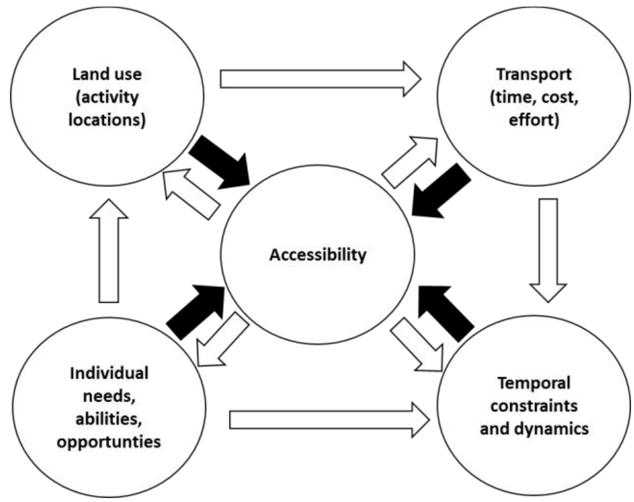
The temporal component reflects the temporal dynamics in transport impedances and temporal constraints of individuals such as the availability of opportunities at different times of the day, and the time available for individuals to participate in certain activities (e.g. work, recreation). A growing field of accessibility modelling is related to temporal dynamics in accessibility. In the recent past, mainstream accessibility models were static measures of access, since the score for a particular location does not vary temporally, which as a result may not suitably represent the actual levels of access for different population groups and activity purposes. However, nowadays, time-of-day variations in road network accessibility can be examined using real-time driving speeds on road networks based on GPS measurements from mobile phones and navigation systems such as TomTom or NavTeq (e.g., Moya-Gómez and Garcia-Palomares, 2015). Recent advances in geospatial technology, open source web-based mapping (e.g., OpenStreetMap) and public availability of Transit Feed Specification (GTFS) data from transit authorities gives room for a growing field of research on time-of-day variations in public transit accessibility (e.g., Owen and Levinson, 2015).

The individual component reflects the needs (depending on age, income, educational level, household situation, etc.), abilities (depending on people's physical condition, availability of travel modes, etc.) and opportunities (depending on people's income, travel budget, educational level, etc.) of individuals to travel and access spatially distributed opportunities.

These components interact in multiple ways, as illustrated in Figure 1. For example, changes in the transport system (e.g. investments in new infrastructure) may induce changes in the land use system (location decisions of households and firms) and vice versa.

To date, a major challenge in accessibility studies is the balanced treatment of the four components of accessibility. A detailed treatment of all four components of accessibility would create a comprehensive but also very complex measure of accessibility which is beyond the state of art in accessibility research and practice. Transport planners tend to focus on the transport component of accessibility, typically using transport demand models and distinguishing between various time and cost impedance factors (e.g. travel and waiting time, reliability, comfort, fuel costs) in the analysis, but ignoring the land-use and individual components of accessibility. Urban planners and geographers (e.g., human geography, health geography) typically focus on the land-use component and less on the transport component of accessibility (e.g., using on crow-fly distance or travel time isochrones) and differences between population segments. Furthermore, there is often a lack of attention for the interactions between the different components of accessibility. Relatively little accessibility studies are for example conducted within land-use transport interaction frameworks.

Figure 1. The four components of accessibility and their interactions



Source: Based on Geurs and Van Wee (2004).

3. Accessibility measures: A brief overview

There are many different possible categorisations of accessibility measures. Geurs and Van Wee (2004) distinguish four basic perspectives on accessibility. These are briefly described below with typical examples of accessibility indictors.

3.1. Infrastructure-based measures

This perspective is typical domain of civil engineers, transport engineers and planners. These range from simple to link-based travel speed and congestion indexes to more complex network-based measures analysing the relative performance of a node or an area in the transport network, based on graph theory. A first example of this type is the access cost indicator. This index is the summation of all travel impedances (time and/or costs) of area *i* to all areas *j*, divided by the number of locations. The lower its value, the more accessible a location is. Variations involve the weighted by actual or modelled origin-destination trip pattern or the probabilities of trips taking place between *i* and *j* (e.g., see Linneker and Spence, 1992).

A second example is the public transport connectivity index. A relatively well-known example is the Public Transport Accessibility Level (PTAL) used by Transport for London (TfL) in the United Kingdom to assess the access level of geographical areas to public transport. PTALS measure the accessibility of a point to the public transport network, taking into account walk access time and service availability. The method is essentially a way of measuring the density of the public transport network at any location within Greater London (TfL, 2015).

3.2. Location-based accessibility measures

Location based measures can be used from the perspective of the origin, e.g. the location of the dwelling of a person, or from the perspective of the destination, e.g. a location of a shop, expressing, for example, the potential number of clients. There are many different operationalisations used in the literature. Most of accessibility instruments in the urban planning practice in Europe are based on location-based accessibility indicators (e.g., see Hull et al., 2012). The two most popular location-based measures are cumulative opportunity (threshold) measures and potential accessibility. The cumulative accessibility measure (CUM) is a simple indicator expressing the absolute number of opportunities within a specified cutoff travel impedance (e.g. 30 minutes). The functional form in its simples form is as follows:

$$CUM - A_i = \sum_{j=1}^{n} D_j P(t_{ij}) \tag{1}$$

where $P(t_{ij}) = 1$ if t_{ij} < cutoff value and 0 if t_{ij} > cutoff value.

The potential accessibility measure, or gravity-based measure, estimates the accessibility of opportunities in zone *i* to all other zones (*n*) in which smaller and/or more distant opportunities provide diminishing influences, and is based on the notion of potential which dates back to the social physics school in the 19th century. The literature gives a wide range of forms (see for example Fotheringham and O'Kelly, 1989; De Vries et al., 2009) with the exponential and power formulation as basic forms where for short distances the exponential form is usually adequate and the power function usually yields the best fit. The power form was used by Hansen (1959) but the negative exponential form appears to be the most popular, given also their theoretical roots in the entropy maximising approach (Reggiani et al., 2011). A potential accessibility measure PA using a negative exponential cost function, has the following form:

$$PA_i = \sum_{j=1}^{n} D_j e^{-\beta c_{ij}} \tag{2}$$

where PA_i is a measure of accessibility in zone *i* to all opportunities (mass) D in zone *j*, c_{ij} the costs of travel between *i* and *j*, and β the cost sensitivity parameter.

Contour measures and potential accessibility measures implicitly assume that the demand for available opportunities are uniformly distributed in space, and do also not account for capacity limitations of available opportunities (whereas jobs can only be for one worker at any moment in time). In other words: they do not handle competition effects. This may lead to inaccurate or even misleading results (Shen, 1998). To incorporate these competition effects, several authors developed alternative accessibility measures based on potential accessibility measures. The approaches can be grouped by three categories. Firstly, a number of authors tried to incorporate the effects of competition on opportunities in accessibility measures by evaluating both the opportunities within reach from origin zone *i* (the "supply" potential) and the relevant population within reach from the same origin zone *i* (the "demand" potential) and dividing the two. This approach evaluates the accessibility of supply and demand at the same location and therefore is not suitable for applications such as job accessibility, where the distance between demand and the opportunity where this demand is met (between one's home and one's job) can be considerable. When looking for a job, one considers jobs in the area that can be reached from one's residential zone *i*. When one applies for a job in employment zone *j*, one has to compete with other applicants that live in the area that can be reached from that zone *j*.

A second approach, taken by for example Joseph and Bantock (1982) and Shen (1998), does evaluate the accessibility of supply and demand at different locations and therefore seems more suitable for our purpose. The basic idea is to divide the supply located in destination zone *j* by the relevant population within reach from that zone *j* (the "demand" potential) and then evaluate the resulting "relative supply" for all destination zones within reach from origin zone i. Joseph and Bantock (1982) used this approach to develop a measure for the potential accessibility to general practitioners. The potential accessibility of origin *i* to general practitioners is calculated by first dividing the number of general practitioners in each zone *j* by the potential demand within the catchment area of those general practitioners, and then evaluating the resulting quotient for all zones *j* reachable within a certain travel distance from i. Joseph and Bantock's measure is shown in equation 3.

$$A_i = \sum_{j=1}^{n} \left[\frac{GP_j}{\sum_{i=1}^{m} P_i F(d_{ji})} \right] F(d_{ij}) \tag{3}$$

Where A_i presents the potential accessibility of area *i* to general practitioners, GP_j,the number of general practitioners at area *j* within range of area *i*, Pi the population within the doctors' catchment area, and $F(d_{ij})$ a function of the distance decay between *i* and *j*. Shen (1998) refines this approach by including mode choice in the analysis of job accessibility. A similar approach is popular in health geography, called the (two-step) floating catchment area measure to examine access to primary health care facilities (e.g., Dewulf et al., 2013). It should be noted that this approach incorporates competition effects at destinations only. The availability of a doctor decreases as the demand by the population living around that doctor's practice increases, but the method does not reflect the fact that the demand by the population on a doctor decreases with the number of other doctors that have a practice in the neighbourhood. This may lead to overestimation of the competition effect.

A third approach involves interpreting the balancing factors A_i and B_j of the doubly-constrained spatial interaction model as accessibility measures (Williams and Senior, 1978; Wilson, 1971). The (inverse) balancing factors are represented in the following equations:

$$A_i = \sum_{j=1}^{m} \frac{1}{B_j} D_j F(d_{ij}) \qquad B_j = \sum_{i=1}^{n} \frac{1}{A_i} O_i F(d_{ij}) \tag{4}$$

In the interaction model, the balancing factors serve to ensure that the magnitude of flow (e.g. trips) originating from and destined to each zone equals the correct number for that zone (e.g. inhabitants or jobs). Since they are mutually dependent, they have to be estimated iteratively. The functional form of the inverse balancing factors is very similar to the potential accessibility measure and the index of Joseph and Bantock. In fact the first iteration in their estimation is equivalent to computing the demand potential for all zones and the second iteration is equivalent to computing Joseph and Bantock's measure. In the third step, demand in all zones is divided by this measure and then used to compute a modified demand potential. Next, supply in all zones is divided by this modified demand potential and used to compute a modified supply potential and so on, until convergence is reached. In this way, the mutual dependence between the competition on supplied opportunities and the competition on demand is reflected in the inverse balancing factors. The balancing factors have for example been applied to examining job accessibility by car and public transport in the Netherlands (Geurs and Ritsema van Eck, 2003).

3.3. Utility-based accessibility measures

This economic perspective on accessibility is founded in the economic utility theory of choice behaviour (e.g. see Burns and Golob, 1976; de Jong et al., 2007; Geurs et al., 2010b). The focus is on analysing the welfare benefits that people derive from levels of access to the spatially distributed activities. Several utility-based measures of accessibility have been developed, depending on the modelling framework used. Probably the most well-known measure is the logsum measure derived from the multinomial logit model. Publications on the logsum as a measure of consumer surplus (the difference between the market value of a good or service and the value for the user) date back to the early 1970s. Here, we briefly introduce the concept of the logsum which is sometimes applied in transport planning and transport appraisal (Geurs et al., 2012; Zondag et al., 2015). The "log-sum" term is the log of the denominator of this logit choice probability, i.e. the sum of exponentially transformed utilities of the alternatives in a choice set. It gives the expected maximum utility associated with a traveller's choice set. This is simply the outcome of the mathematical form of the extreme value distribution associated to the logit model. Logsum accessibility can be expressed in monetary terms, defined as the utility in money terms, that a person receives in the choice situation (also taking account of the disutility of travel time and costs). Person *n* chooses the alternative that provides the highest utility, so that, provided that utility is linear in income, the accessibility benefit can be calculated in money terms, multiplying the logsum by the inverse of the marginal utility of income. Usually, a price or cost variable enters the representative utility and, in case that happens in a linear additive fashion, the negative of its coefficient is αn by definition.

$$A_n = (1/\alpha_n)\ \ln \sum_{j=1}^{J^1} e^{V_{nj}} \qquad (5)$$

The (1/α) factor is the trade-off between accessibility and money. When α is low, so that (1/α) is high, the weight of the price in the underlying utility function is low which implies a high willingness to pay for accessibility improvements, implying a high economic value of a given accessibility increase. The logsum measure is not often used in practical applications (see for an overview de Jong et al., 2007). Examples are found in Niemeier (1997), who analysed mode-destination accessibility for home-to-work trips in Washington State and Geurs (2010, 2012) who analysed the accessibility benefits of integrated spatial planning and public transport investments in the Netherlands.

An alternative approach to measuring utility-based accessibility is developed by Martínez and Araya (2000), who developed transport-user benefit measures derived from the doubly constrained spatial interaction model. This approach has also been applied by Geurs et al. (2006).

3.4. Person-based accessibility measures

Person-based measures analyse accessibility at the level of the individual level, e.g. the activities in which an individual can participate at a given time. This type of measure is founded in space-time geography (Hägerstrand, 1970). Person-based measures recognise that activity participation has both spatial and temporal dimensions, that is, activities occur at specific locations for finite temporal durations (Miller, 1999). Person-based measures express personal accessibility in terms of the space-time feasibility of opportunities to an individual using the volume of the (three-dimensional) space-time prism (or potential path space [PPS]) or the number of opportunities in its projection on planar space (potential path area [PPA]) as indicators. They are person-specific measures that provide a framework for incorporating the spatial configuration of the transportation system, spatial distribution of urban opportunities, and individual spatio-temporal constraints into a single measure of accessibility (Kwan, 1998). In the early 1990s, methods were developed to estimate person-based measures using GIS procedures. Miller (1991) developed network-based space-time accessibility measures using generic GIS-based procedures dealing with link-based travel velocities and thus incorporating transport network characteristics. Various person-based accessibility measures have been developed in the literature, depending on, amongst others, the treatment of opportunities (dichotomous, cumulative, weighted) within the PPA.

Hybrid approaches between utility-based and person-based accessibility have also been developed. Miller (1991) developed a utility-based space-time accessibility measure representing an individual's benefit to perform an activity in space and time. Dong et al. (2006) and Neutens et al. (2010) developed similar approaches rooted in utility-maximisation theory, estimating a logsum within a space-time framework, expressing the individual's expected maximum utility over the choices of all available activity patterns.

4. Accessibility indicators: a review of strengths and weaknesses

4.1. Introduction

Several studies in the accessibility literature show that the conclusions of accessibility effects of choice options strongly depend on the accessibility measure chosen and its operationalisation (e.g., see Geurs and Ritsema van Eck, 2001; Kwan, 1998; Linneker and Spence, 1992; Neutens et al., 2010; Thill and Kim, 2005). For example, Linneker and Spence (1992) examined the accessibility impacts of the construction of the M25 London Ortibal Motorway using location-based (Hansen-based accessibility) and infrastructure-based measures (access-costs); they conclude that the measures provide very different results. Thill and Kim (2005) correlate 72 different specifications of location-based measures (gravity and cumulative-opportunity measures) to trip generation and find that different accessibility metrics often work together to explain trip making at the aggregate or disaggregate level, and thus capture different facets of accessibility. Kwan (1998) specified and applied 18 different specifications location-based (gravity and cumulative-opportunity) and 12 person-based accessibility measures, and concludes that location-based and space-time measures are distinctive accessibility measures which reflect different dimensions of accessibility, i.e. space-time measures are more capable of capturing interpersonal differences. Finally, Neutens et al. (2010) examined four place-based and six people-based measures that are frequently used to evaluate urban service delivery, and supports Kwan's findings. In addition, Neutens et al. also observed substantial differences within the group of person-based measures.

Geurs and Van Wee (2004) argue that the choice of an accessibility indicator depends on the goal of the study and the importance of the theoretical basis, the ease of operationalisation, interpretability and communicability and usability in social and economic evaluations. Based on these criteria, the report will now discuss the theoretical and practical strengths and weaknesses, and the usability in social and economic appraisal, of five well-known accessibility measures, which are also summarised at the end of the section in Table 1:

- infrastructure-based accessibility: network connectivity measure
- location-based accessibility: cumulative opportunity measures (CUM) and potential accessibility (PA)
- person-based accessibility: network based potential path area (PPA)
- utility-based accessibility: logsum accessibility.

4.2. Theoretical strengths and weaknesses

Geurs and van Wee stated that an accessibility measure should ideally take all components and elements within these components into account. Thus, an accessibility measure should firstly be sensitive to changes in the transport system, i.e. the ease or disutility for an individual to cover the distance between an origin and a destination with a specific transport mode, including the amount of time, costs and effort. Secondly, an accessibility measure should be sensitive to changes in the land-use system, i.e. the amount, quality, and spatial distribution of supplied opportunities, and the spatial distribution of the demand for those opportunities, and the confrontation between demand and supply (competition effects).

Network connectivity indicators are among the most basic measures of infrastructure-based accessibility where a network is represented as a connectivity matrix, which expresses the connectivity of each node with its adjacent nodes. This measure is rooted in graph theory, a branch of mathematics concerned about how networks can be encoded and their properties measured. However, network connectivity measures have a weak theoretical basis since they are only concerned with the measurement of the performance of the transport system (only transport component) and thus represent a partial analysis of accessibility.

Simple location-based measures such as cumulative opportunity measures (CUM) are very popular in urban planning but have a weak theoretical basis. Firstly, a main difficulty remains for all CUM measures in their arbitrary selection of isochrone increments and the travel time limit. Secondly, as the more distant opportunities are given equal weights to the closer ones, the value of this index increases steadily with increase in the travel time limit. This undesirable characteristic due to the lack of "spatial discounting" has been noted frequently in the literature and is problematic from a travel behaviour perspective (e.g. Kwan, 1998). However, many variations of CUM have also been developed. For example, Black and Conroy (1977) developed a CUM index that measures the area under the curve of the cumulative distribution of opportunities reached within a specified travel time from the origin. As distance decay is modelled by a negative linear impedance function, their index takes into account the spatial distribution of opportunities in a study area. Also, CUM indexes are developed to take into account competition effects. These are particularly popular in health geography where thethe two-step floating catchment area index is often applied. This index estimates the ratio of the number of supplied health facilities within a certain travel time to the demand (population) that can reach those facilities (e.g. see Dewulf et al., 2013). Variations of this approach using potential accessibility have also been in use since the 1980s, e.g. to measure access to general practitioners (Joseph and Bantock, 1982).

Potential accessibility (PA) modelling deals with the two CUM disadvantages mentioned above. PA models are rooted in spatial interaction models. It is well known in the literature that there are strong links between potential accessibility, spatial interaction models and discrete choice models. Spatial interaction models have various theoretical roots, but the most common specification originates from entropy theory. Spatial interaction and PA models have been criticised for being a non-behavioural modelling approach, as spatial interaction and accessibility not explicitly based on perceived user's attributes. Anas (1983) observed that entropy-maximising spatial interaction models (SIM) and multinomial logit models are analytically compatible. It is not surprising therefore that it can be shown that the potential accessibility and logsum measure have several features in common. Some of the obvious differences between the logsum and the potential accessibility measure relate to differences in conventions adopted in the various domains for using a default specification. An essential difference is the logarithmic transformation which is missing in potential accessibility, resulting in the crucial difference between accessibility and the utility of accessibility: an absolute change in accessibility measured has a welfare impact that depends on the initial level of accessibility.

Logsum accessibility has been advocated as an accessibility measure by several authors in the literature as it provides a closed form expression for accessibility well founded in discrete choice theory. This gives the logsum a robust theoretical underpinning. De Jong et al. (2007) give an overview of applications of the logsum. Recent examples include Dong et al. (2006) and the paper of Geurs et al. (2010) as discussed above. A major strength of the logsum lies in the variety of attributes of the alternatives that it can encapsulate within a single term. The logsum is derived from the MNL specification and the specification of the discrete choice models is flexible. This flexibility allows accessibility models to be extended to include perceptions of transport attributes, if these are to be incorporated in the utility definition. Discrete choice models and accessibility estimations are typically based on travel time and travel cost variables. Psychological factors and perceptions determining the transport component of accessibility are typically excluded, e.g. comfort, safety. La Paix and Geurs (2016) are probably the first who estimate hybrid choice models to include latent variables in the impedance function of access mode choice of train stations.

The logsum also has theoretical disadvantages related to the choice modelling framework which are relevant for accessibility evaluations. The first criticism is that the Multinomial Logit model does not account for unobserved taste variations and not all options are available to all individuals. Moreover, to date all logsum measures are based on multinomial logit specifications which suffer from the property of independence of irrelevant alternatives, which leads to a decreasing probability of viable choices (Martinez, 1995). A solution for these issues would be to use a mixed logit approach. The logsum can be calculated and by integrating over the mixing distribution we obtain a population value. Thus if unobserved taste variation is represented in the model by using mixed logit models, then the "mixed logsum" is a valid construct and is justified on the same basis as the simple logsum (de Jong et al., 2007). However, there are no apparent examples of mixed logsum applications in the accessibility literature thus far.

The logsum also has limitations related to the treatment of the choice set. Firstly, there are no natural constraints to the choice set (Bhat et al., 2000). Secondly, an important limitation of the logsum is that only the utility of the choices made is counted. The only reason to include more options in the logsum than the alternative with the best utility performance is the stochastic element. The difference between the cases of uncertainty and complete certainty is only gradual, however, since the result for complete certainty just follows as a special case of the logit model. Literature on the option value explains that people might value options that they have available (in this case: options to reach destinations, use modes or maybe even routes) that they do not use (Geurs, 2007; Laird et al., 2009). This notion is also reflected in well-known definitions of accessibility. For example, Hansen (1959) was the first to define accessibility as "the potential of opportunities for interaction" and Geurs and van Wee (2004) as "the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations by means of a (combination of) transport mode(s)". So, options to participate in location based activities are inherently relevant if accessibility needs to be operationalised. Defining accessibility in terms of opportunities is also in line with the concept of choice which assumes that societal welfare increases if more choice options are available (Metz, 2008).

Person-based accessibility measures are theoretically advanced accessibility measures as they add temporal constraints to the conceptual framework of accessibility, which are lacking in standard location-based and utility-based measures. In practical applications, however, the person-based measures lack attention for competition effects (similar to standard potential accessibility measures) and often simplify the transport component of accessibility, i.e. focusing on Euclidian or shortest-path travel times between locations excluding delays and congestion, and excluding other impedance factors such as transfer time, travel costs, and efforts.

4.3. Practical strengths/weaknesses

In choosing accessibility measures, there clearly is a trade-off between theoretical and practical strengths/weaknesses. The simple network-based and cumulative accessibility measures have practical advantages related to the operationalisation, interpretability and communicability of the indexes. These measures are relatively undemanding of data and are easy to interpret for researchers and policy makers, as no assumptions are made on a person's perception of transport, land-use and their interaction. However, these accessibility indexes clearly do not satisfy most of the theoretical criteria. Utility-based and person-based accessibility measures have a strong theoretical underpinning but are very data demanding (person-based measures), as less easily aggregated and communicated (person-based measures) or are less easily explained or understood (logsum). The logsum measure of accessibility, however, does have practical advantages since calculations of utility changes of a policy measures can straightforwardly be based on discrete choice model that are typically used to forecast transport. Thus there is no need to run additional models or carry out further data analyses, e.g. based on GIS systems. A second practical advantage is that the logsum allows for evaluating the accessibility over a large area, whereas some of its competitors, especially the location-based accessibility measures, are primarily useful to express accessibility levels of specific locations (either origins like residential areas, or destinations like job locations or services). At the same time, a practical disadvantage of the logsum is that logsums per transport mode or zone cannot easily be calculated, since modes and zones are endogenous choice variables (Geurs et al., 2010b; Kohli and Daly, 2006) This disadvantage can be overcome by using approximation. For example, Geurs et al. (2010) assign logsum results by modes by approximation based on the transport-mode choice probabilities and the sum of utilities over all alternatives within a transport-mode. A similar approach can be used, for example, to estimate logsums by transport origin zone.

4.4. Usability in economic evaluations

Utility-based accessibility measures are the only type of accessibility measures which can directly be used in economic appraisal (i.e. cost-benefit analysis) of transport investments. In particular, the logsum provides an elegant and convenient solution to measure the full direct accessibility benefits from land-use and/or transport policies (Geurs et al., 2010). Logsum accessibility, derived form a mode/destination choice model, can account for changes in (generalised) transport costs, destination utility and trip production, and is thus in theory capable of providing the accessibility benefits from changes in the distribution of activities, due to transport or land-use policies. Geurs et al. (2010; 2012) show in two case studies for the Netherlands using a land-use/transport interaction framework that logsum accessibility benefits from transport investment strategies are 20 to 70% higher than the rule-of-half as the result of changes in origin and destination patterns (e.g. residents moving house). In standard accessibility evaluation with the rule-of-half method, the accessibility benefits from land-use changes are not measured and would need to be measured in the land-use system (e.g. using property values or land rents). In practice, it is quite difficult to identify and measure these benefits within the land-use system, especially in regulated land markets and housing markets (Geurs et al., 2010). Note that potential accessibility measures and spatial-interaction models have traditionally been used in population modelling and spatial-economic forecasting. Hansen (1959), for example, in his seminal paper on accessibility, used gravity-based accessibility to forecast population growth in zones Washington D.C..

4.5. Usability in equity and distributive justice evaluations

People, groups of people and regions inevitably do not have equal access to destinations, such as shops, jobs or medical services. Several measures of equity are used in the literature and planning practice (Di Ciommo and Shiftan, 2017). Moreover, the unequal access is not necessarily problematic, but some distributions can be considered as “unfair”. But for moral judgements (what is fair?) it is not only the distribution of access to destinations that matters, but in some cases also the absolute level of access of those who are worse of. So, “equity”, contrary to “distribution”, includes a moral judgement, and goes beyond simply estimating the distribution of accessibility by area and/or population group.

Van Wee and Geurs (2011) state that there are least three theories on ethics relevant for evaluating the social justice of inequalities in accessibility: utilitarianism, egalitarianism and sufficientarianism. Utilitarianism is strongly related to cost- benefit analysis (CBA): a CBA lists all pros and cons as much as possible in monetary terms and compares alternatives using indicators like benefits minus costs, benefit to cost ratio, and return on investments. Choices of travellers are based on their willingness to pay (WPT) for travel options. As a point of departure we think this makes sense, and it is at least consistent with the utility based framework of CBA. Lucas et al. (2016) state that although this framing can be useful for many areas of policy delivery, especially where the aim is to maximise the benefits of an investment for all members of society, it is not appropriate when there is specific aim to achieve greater equity from that investment. They suggest that egalitarianism and sufficientarianism more adequately justify policies that specifically aim to redistribute transport resources towards currently disadvantaged population groups and deprived areas (Lucas et al., 2016).

Egalitarianism is an influential category of theories on ethics. Egalitarians hold the premise that all people should be treated equally; their theories differ from utilitarianism. An important theory in this category is Rawls’ theory of justice (1971), which is described in detail by Pereira et al. (2017). Rawls argues that justice should focus not on welfare, but on the provision of certain kinds of goods he labelled “primary” for all people. Egalitarian theories focus on interpersonal differences in well-being, not on absolute levels of well-being. Lucas et al. (2016) conclude that egalitarian theories are particularly useful to legitimate policy that aims for equality of accessibility. However, Nahmias-Biran et al. (2017) argue interpersonal comparisons of equity are problematic as people may differ in the relative value they attach to different goods. If a set of different goods is used as an indicator of fairness, it becomes impossible to compare the relative position of two different people without making (paternalistic) value judgements regarding the relative importance of the different goods that make up the set.

Another important criticism of Rawls' theory comes from Amartya Sen who proposes that the focus of the difference principle should shift from primary goods to human capabilities. Pereira et al. (2017) give a good description of Sen's capability approach. Sen argues that questions of distribution should focus on functionings and capabilities, rather than on resources such as primary goods, as upheld by Rawls. Nussbaum constructed the notion of "basic capability" and extended Sen's theory. The sufficientarianism approach is it concerned with promoting basic capability equality by guaranteeing minimum levels of basic capabilities. To date, various authors have argued that mobility in the sense of being able to move should be considered as a basic capability because of its central role in enabling people to satisfy basic needs, and more recently accessibility is interpreted as a capability. However, the application of the sufficientarianism approach to accessibility raises challenges. Pereira et al (2017) state that understanding accessibility in capability terms couples accessibility needs with the idea of social rights insofar as some minimum level of accessibility is necessary for the satisfaction of individuals' basic needs and a necessary, though not sufficient, condition for people to exercise basic rights such as going to school, receiving healthcare, and voting in elections. It certainly requires the identification of minimum acceptable thresholds of accessibility to key activities and demands government initiatives to guarantee the accessibility needs of people who fall below those thresholds. The identification of such minimum thresholds remains an unresolved challenge in the academic literature. An example of an operational criterion could be that households should have a shop selling food within reach of a certain non-care-based travel time interval. Accessibility measures which can be used to address sufficientarianism are not easily defined and operationalised. If certain minimum levels of accessibility of destination categories are to be included, what are the minimum levels? Should meeting these levels be included as a 0-1 variable, or should a form of distance decay or other weighting be added? How should access to different destination types be compared? Can access to different destination types (work, health, shops etc.) be aggregated, and if so, how?

Strengths and weaknesses of accessibility indicators in equity evaluations

A growing field of literature discusses the importance of the accessibility concept to examine equity and distributive justice of transport policies (Beyazit, 2011; Lucas et al., 2016; Nahmias-Biran et al., 2017; Pereira et al., 2017). The choice and operationalisation of accessibility indicators for equity and distributive justice is however still open for discussion. It requires a more complete understanding of accessibility than traditional indicators offer, and also depends on the theory of justice used. In the selection of appropriate accessibility measures as equity, egalitarianism and sufficientarianism indexes, a balanced treatment of the four components of accessibility is particularly relevant. It implies that the land-use, transport and temporal components are incorporated at a sufficient level of detail. A balanced treatment already implies that infrastructure-based accessibility measures are not suited to social evaluations, as they lack the land-use component of accessibility. Location-based, person-based and utility-based measures are potentially suited. Already in the early 1970s, CUM and PA measures were used frequently to assess the spatial equity (differences in the spatial distribution of accessibilities) and social equity (differences in accessibilities between different population groups) issues (e.g., Black and Conroy, 1977; Wachs and Kumagai, 1973).

Also comparative studies have been done. Neutens at al. (2010) applied location-based (CUM and PA measures) and different person-based accessibility measures to examine spatial equity in access to government services for male and females. In analysing equity and justice implications of accessibility it is also important to account for competition effects (thus implying a detailed treatment of the land-use component). The supply of primary social goods such as health care and schools but also employment opportunities by definition limited, implying spatial competition effects. In the literature, adapted CUM and PA measures including competition effects (2SFCM and similar approaches) have been used in the literature to examine spatial and social equity issues, such as access to public playgrounds (Talen and Anselin, 1998), job opportunities for low-skilled workers (Shen, 1998), and job accessibility for low-income and ethnic groups (Grengs, 2012). I am not aware of studies using person-based accessibility measures that have included competition effects.

The treatment of the individual component in accessibility is crucial in equity and distributive justice evaluations. From egalitarianism theory, the goal is to examine interpersonal differences in access to spatially distributed opportunities and it is thus important to explicitly incorporate differences in needs, abilities and opportunities between individuals or between groups. A sufficientarianism approach should reflect the relevant personal characteristics that shape a person's possibilities to translate a resource ("objective" accessibility) into a capability ("experienced" accessibility).

PA models can use different distance decay functions and logsum accessibility reflects different utility functions for different population segments depending on income, for example. Person-based accessibility measures are developed to measure accessibility at the individual level partly in response to the recognition that location-based measures are less suited to understanding the complexities of and individual difference in human spatial behaviour (Kwan and Weber, 2003). Person-based measures have advanced in the treatment of the individual component but probably do not sufficiently capture all dimensions of social justice theory. Biran et al. (2017) interpret the logsum as an appropriate measure to determine a person's level of capability, and thus a suitable indicator for the capability approach.

However, egalitarian theories assume everybody should be treated equally and should be equally well-off, and sufficientarianism assumes that everybody should be well-off up to a certain minimum threshold, which is "sufficient" for fulfilling their basic needs and to guarantee their continued wellbeing. Accessibility indices which for example explicitly discounts opportunities by personal characteristics, or use higher WTP for high-income groups, do not treat everyone as equal. Disadvantaged groups and low-income groups for example have shorter commuting trips than high-income groups, which have a higher WTP for commuting and thus have a more steep distance decay function. Estimating potential accessibility with different commuting distance decay functions by income group will thus result in higher job accessibility levels for high-income groups, given the amount and spatial distribution of jobs. In addition to this, monetising utility-based measures such as the logsum is also problematic. Low incomes are often the very reason for social exclusion, and WTP of low-income people for (additional) travel is inherently low because they need about all their income for housing, food, clothes and medical services, leaving hardly any money for travel. In the logsum measure that α tends to be high for low-income households, and then the $(1/\alpha)$ factor in (equation 5) makes the valuation of the accessibility increases low. Thus, accessibility measures which are argued to be theoretically strong and suitable for economic appraisal are not necessarily suitable in equity and distributive justice evaluations.

In the case of sufficientarianism, the main challenges will then be to set threshold values for accessibility at which it can be assumed individuals will become "socially excluded". There is very little literature on this. Simple distance decay functions or cut-off points derived from travel surveys are probably not sufficient. Studies on subjective accessibility (e.g., Cascetta et al., 2013) and literature on travel, subjective well-being and happiness can be relevant here. There are, for example, relevant studies on commuting. In a recent paper, Lancée et al (2017) review literature on commute duration and well-being. Commuting is typically negatively associated with satisfaction with the commute, and longer commuting time is associated with lower life satisfaction. At the same time, some studies have indicated that the relationship between commuting time and subjective well-being is non-linear. Research in the United Kingdom also indicates that each successive minute of travel decreases the level of life satisfaction. Average mood levels significantly drop after 15 min of commuting and life satisfaction after 45 min of commuting. In general, commuting times between 60 and 90 min are most detrimental to subjective well-being levels. In addition, based on the “Happiness indicator” survey in the Netherlands, Lancée et al (2017) find that is not the commuting time per se that depresses a person’s mood, but specific combinations of commuting time and commuting mode. Increasing commuting times can even lead to an uplift of mood when the commute is by bike or foot.

Further research is needed to discuss which accessibility measures are conceptually consistent with different ethical frameworks and to discuss the challenges of building more comprehensive accessibility measures that go beyond the limits imposed by data conventionally used in transport surveys (Pereira et al., 2017).

Statistical measures of inequality

To examine accessibility in equity valuations, the first step is to identify appropriate measures of accessibility, as described above. The second step is to identify indicators to measure the distribution of accessibility between different social groups and/or areas. To examine inequalities, often statistical index indicators based on the Gini or Theil index are used expressing levels of (in)equity. The Gini index is widely accepted as a statistical measure of inequality, often focusing on distribution of income over the population of a country. The Gini-index varies between 0 and 1, with higher coefficients representing higher levels of inequality. A major advantage of the Gini index over other equality indices is that it is scale independent (insensitive to changes in measurement, such as currency or price year in case of income). The measure of sufficientarianism is described by the slope of the Lorenz curve up to the threshold value. In a recent paper, Lucas et al. (2016) used a Gini-index based on a “cluster accessibility index” measuring the shortest distances from home locations to a set of primary services, and cumulative accessibility indicator as a sufficientarianism index.

Table 1. Accessibility measures, applications, theoretical basis, ease of operationalisation and interpretation, and possibilities to include in economic and social evaluations

	Accessibility measure type				
	Network connectivity	Cumulative opportunities	Potential accessibility	Potential path area	Logsum accessibility
Applications	Insight in relative quality of infrastructure networks	Suitable for insights in options to participate in activities.	Suitable for insights in options to participate in activities.	Suitable for insights in the level to which people can fulfil activity patterns depending on constraints	Estimation of the value of accessibility, economic appraisal of transport and land-use projects.
Theoretical basis	Weak. Based on graph theory. Partial analysis of accessibility (only transport component)	Weak. Behavioural dimension is lacking. Adapted CUM can account for competition effects	Strong links to spatial interaction modelling; entropy theory. Adapted PA models can account for competition effects	Founded in time-space geography. However, PPA models do account for competition effects.	Founded in welfare economics, linked to discrete choice theory
Ease of operationalisation	Easy if network characteristics and a transport model are available	Easy	Moderately easy (e.g., potential measures)	Very data demanding, not easy to operationalize	Modest. Only easy if one has an adequate discrete choice based disaggregate transport model
Interpretation/ communication	Moderately easy to interpret and communicate to planners and general public	Easy	Moderately easy	Good for experts, but difficult to communicate to general public and planners. Results are estimated at individual level and not easily aggregated.	Good for experts, but difficult to communicate to general public and planners. Results of different case studies are not easily compared
Usability in economic appraisal	Quantitative estimates of congestion are easily included, other indicators: generally poor.	Poor	Can form input for analysis of economic resilience and competitiveness.	Difficult, although links with utility-based measures have been established	Very good, best of all categories of measures.
Usability in equity evaluations	Not suitable for equity evaluations	Suitable for equity evaluations, usable proxies egalitarianism and sufficientarian-ism indices	Suitable for spatial and social equity evaluations, aggregate PA can be proxies for egalitarianism and sufficientarianism indices	Suitable for spatial and equity evaluations.	Doubtful when monetised

5. Accessibility measures in the Dutch policy and planning practice

5.1. Dutch national transport policy

Since the start of the Dutch national transport policy there have been four major national transport policy documents. This paper summarises the main policy concepts used in these documents for surface-based passenger transport. A more elaborate discussion can be found elsewhere (Geurs and Halden, 2015).

Dutch national transport policy has focused on transport performance-based indicators and targets. In each new policy document, new transport performance-based accessibility standards were developed for the main road network. Quantitative transport performance targets are mainly formulated for road networks and not for public transport or freight networks. Since the 1980s, the national transport model system (LMS) has been used for transport analysis and estimating infrastructure-based accessibility measures. In the 2000s, the Mobility Policy Document (MinV&W, 2006) directed the policy aims towards "reliable and predictable door-to-door travel times". Three types of transport performance-based accessibility targets were set. Firstly, a travel time reliability target was set, based on transport model estimations. By 2020, travellers should reach their destination on time in 95% of cases. Secondly, a travel time target was set. Rush-hour travel times were not to exceed 1.5 times the off-peak journey time on motorways or two times the off-peak journey time on urban orbital roads and non-motorway roads managed by the state. This would make the average motorway rush-hour journey time over a distance of 50 kilometres 45 minutes at maximum (maximum delay of 15 minutes). Thirdly, and finally, an accessibility target was defined in terms of vehicle-hours lost; the number of hours lost in 2020 should be reduced to the level of 1992. In addition, to a limited extent quantitative accessibility objectives were also formulated for other modes; for example, in terms of arrival reliability of trains.

The current policy document, the National Policy Strategy for Infrastructure and Environment (MinIenM, 2012) is the first policy document in which spatial planning and transport policy are integrated in a single document. This is the result of the merger of the former Ministry of Transport and Water Management and the Ministry of Housing and Physical Planning into the Ministry of Infrastructure and Environment in 2011. However, this did not affect the main perspective on accessibility – the focus remains on infrastructure-based accessibility measures. The travel time target from the 2006 Mobility Policy document is kept as a performance-based accessibility indicator. The "travel time reliability" indicator is replaced by a qualitative aim to achieve "a robust and coherent mobility system". In addition, new infrastructure-based accessibility indicator was announced, replacing the "vehicle hours lost" indicator. The aim of the new indicator was to give a more complete picture of the performance of different transport modes and transport networks (Hoogendoorn-Lanser et al., 2011). This indicator expresses the travel time from areas to overcome the distance to particular destinations with different transport modes.

5.2. Dutch national and regional transport planning and its limitations

Since the early 1990s, the Dutch Ministry of Transport produced Multi-year Programmes on Infrastructure and Transport programme (MIT), describing hundreds of roads, railways, waterway projects involving the national government. The programme has a 15-year time horizon is produced annually as a supplement to the annual State Budget. In 2008, the programme was changed as national funds for infrastructure and spatial developments were merged, resulting in a new Multi-Year Programme for Infrastructure, Spatial Planning and Transport (MIRT) and a revised accompanying framework of rules for the planning, programming and budgeting process. The merger of the two ministries led to a more recent shift from individual infrastructure project planning towards area-oriented planning in the Netherlands, aiming to integrate transport infrastructure planning with other land-use and environmental planning issues, and also establish more collaborative decision making involving national and regional governments (see Heeres et al., 2012 for a discussion and overview). In the MIRT programme, different phases are distinguished: exploratory studies, plan studies and the construction and management/maintenance. In the exploratory phase, studies are conducted at the regional level to explore potential solutions and transport investments, involving national, regional and/or local governments. In the next step of the MIRT process, the planning phase, social cost-benefit analysis is obligatory to examine the economic efficiency of proposed investments.

So far, the Dutch national and regional transport policy and planning processes have relied on infrastructure-based accessibility measures in their spatial planning and transport planning, with policy goals targeting congestion, travel speeds, travel time reliability and service levels (e.g. local PT frequency). Thus, it seems that academic research on accessibility is not followed by applications in the Dutch transport policy and planning practice. This diffusion trend has not been present in accessibility planning practice, where planners have been relatively slow to adopt accessibility metrics. This has a number of strong limitations.

Limitation 1: A sectoral policy approach

It is well-known that accessibility has implications well beyond transport. Health, education and other institutions have policies and responsibilities for ensuring access. Because they integrate location, movement and (potentially) other societal barriers to and enablers of interaction, accessibility instruments can also provide a basis for cross-sector planning. However, Dutch transport planning has focused on applying accessibility indicators in sectoral policy development.

Limitation 2: A lack of attention for interactions between transport and land use

Many land-use/transport interaction (LUTI) models are used by local and regional authorities around the world in their transport planning processes. In the Netherlands, the national LUTI model (TIGRIS XL) has been developed and used in several research projects and scenario studies. Zondag et al. (2015) for example show the added value of embedding accessibility measures within the framework of a LUTI model; modest changes in location choices of residents and firms can have significant effects on the accessibility benefits of public transport investments. However, the Dutch government prescribes stand-alone regional transport models in the transport planning process, and so far LUTI models have not been used in decision making on transport infrastructure investments.

Limitation 3: The treatment of the transport component

Accessibility indicators used in the Dutch policy and planning process focus on travel time. Other elements of the transport component (e.g. travel cost, information, comfort, physical barriers) are virtually absent, and there is little attention for the temporal and individual components of accessibility. Attention for the temporal dynamics in accessibility is also limited, which as a result may not suitably represent the actual levels of access for different population groups and activity purposes.

Limitation 4: A lack of attention for measuring urban accessibility (including walking and cycling)

The policy- and empirically-oriented literature has focused way more often on accessibility by car and public transport, than on accessibility by slow modes. The popularity of cycling in both the literature and policy is rapidly increasing. Van Wee and Geurs (2016) argue that there is a lack of knowledge on how to include cycling in accessibility indicators. Such indicators could include the non-linear travel resistance at longer distances/travel times, mode-specific valuations (in case of utility based measures), and multimodality (e.g. in time-space indicators).

Limitation 5: Lack of attention for equity/distributional and justice effects

Dutch national and regional transport policy and planning hardly pay attention to equity/distributional and justice effects, with spatial distributional effects as an exception in social cost-benefit analysis.

5.3. Dutch national and regional transport planning in transition

Dutch national transport planning seems to be in a transition phase. In the past years, the ambition of area-based planning and integrating spatial and transport planning within the MIRT program has been a struggle. Guidelines for a new generation of MIRT studies were introduced recently in 2016 (called "renewal MIRT"), and tested in a number of MIRT research studies. The starting point is to seek synergies between transport and spatial planning, examine a wide range of policy options including spatial planning, transport demand and supply management strategies, and involve collaboration between national, regional and/or local governments, business and societal organisations. Interestingly, a broader set of accessibility indicators are used in these studies.

A recent example is the MIRT research study conducted in the Rotterdam–The Hague Metropolitan area (MRDH, 2017), a joint study of the Ministry of Infrastructure and Environment, the Province of South-Holland, the Metropolitan Region, and the Municipalities of Rotterdam and The Hague were involved. A aim of the study was to analyse how accessibility improvements can contribute to four societal goals: (1) enhance the spatio-economic structure, (2) to improve the quality and attractiveness of the living environment, (3) reduce social inequalities (a sufficient level of access to jobs, education, services, leisure), and (4) increase attractiveness of the (multimodal) transport system for users of the systems. Improving accessibility is thus seen as a means towards achieving multiple societal goals. Interestingly, this MIRT study moves beyond traditional infrastructure-based accessibility measures, at it focuses on location-based and utility-based measures. CUM indices are used as location-based measures, i.e. the number of people that can reach economic centres within 30 minutes travel time by car and bike, and 45 minutes travel time by public transport. Travel time delays and CUM are estimated using a regional transport model. Interestingly, the CUM index is interpreted as an indicator for agglomeration economies. In addition, the TIGRIS XL LUTI model is used to estimate logsum accessibility benefits of different land-use and transport policy strategies, including spatial planning strategies. One of the main conclusions from the MIRT study is that transit oriented development strategies along the main railway corridors contribute the most to strengthen agglomeration economies and increases accessibility benefits. This is a conclusion which would not have been drawn using the traditional Dutch transport planning approach.

Decisions on the next steps will be prepared in the Area Programme for Rotterdam-The Hague Metropolitan Areas that will result in proposals for inclusion in the MIRT Administrative Consultation in late 2017. Then it can be assessed if the more integrated MIRT research studies result in more integrated decision making on transport and spatial planning, and actual transport investment decisions.

5. Conclusions

There is a considerable diversity in ways of measuring accessibility, and the choice and operationalisation of accessibility indicators can strongly affect the conclusions on accessibility. Within and between the different groups of accessibility measures (infrastructure-, location, person- and utility-based measures) there are can be substantial differences in results, depending on the definition and operationalisation. The choice of accessibility indicators depends on the goal of the study and the importance of the theoretical basis, the ease of operationalisation, interpretability and communicability and usability in social and economic evaluations. In choosing accessibility measures, there clearly is a trade-off between theoretical and practical strengths/weaknesses. The simple network-based and cumulative accessibility measures have practical advantages related to the operationalisation, interpretability and communicability of the indexes. These measures are relatively undemanding of data and are easy to interpret for researchers and policy makers, as no assumptions are made on a person's perception of transport, land-use and their interaction. However, these accessibility indexes clearly do not satisfy most of the theoretical criteria. Utility-based and person-based accessibility measures (and hybrids of the two) have the strongest theoretical underpinning but are very data demanding (person-based measures), as less easily aggregated and communicated (person-based measures) or are less easily explained or understood (logsum).

Comparative studies show that accessibility indicators often work together and capture different facets of accessibility. This diversity indicates that there is no single perfect accessibility measure; rather, it is critical to apply several measures in combination in order to present the necessary information. In particular, location-based and space-time measures are distinctive accessibility measures which reflect different dimensions of accessibility, i.e. space-time measures are more capable of capturing interpersonal differences. This implies that it is better to choose a set of indicators rather than choosing one single best indicator. If national or large scale regional transport policies should be evaluated in a relatively simple way, contour or potential accessibility measures for different activity locations categories (e.g. jobs, shops, schools, medical services, or "other people" can be the indicators of choice. If one aims to evaluate the welfare effects of transport infrastructure projects, or integrated land--use/transport strategies, the logsum indicator is probably the best suited for the job.

The use of accessibility indicators in equity and social justice evaluations has been a topic of debate in recent years. This debate has by far not been settled. Several authors indicated that more research is needed to discuss and develop comprehensive accessibility measures conceptually consistent with different ethical frameworks.

Progress in accessibility analysis is often not matched with advances in the use of accessibility measures in transport policy and planning practice. Handy and Niemeier (1997) already highlighted the gap between academic and practical applications of accessibility, asserting: “It is important that accessibility measures used in practice are theoretically and behaviourally sound and that innovative approaches to measuring accessibility are made practical”. Dutch transport planners have been slow to adopt non-infrastructure-based accessibility metrics. Only in recent years has increasing attention been paid to integrating transport and spatial planning, leading to regional transport planning studies in which location-based and utility-based accessibility measures are used to explore how accessibility improvements can contribute to a wide set societal goals, including economic development and reducing social inequalities. However, it is far from certain that this integrated approach to accessibility is followed in actual national and regional transport investment decisions.

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Transport Planning With Accessibility Indices in the Netherlands

This discussion paper overviews the different perspectives and approaches to measuring accessibility, reviews the strengths and weaknesses of different accessibility indicators and describes the use of accessibility indicators in the Dutch policy and planning practice. In choosing accessibility measures, there clearly is a trade-off between theoretical and practical strengths/weaknesses. Dutch transport planners have focused on infrastructure-based accessibility metrics. Only in recent years, increasing attention has been paid to integrated transport, spatial planning and more advanced accessibility measurements. A growing stream of studies explores the concept of accessibility in order to examine equity and distributive justice of transport policies. The choice and operationalisation of accessibility indicators for equity and distributive justice is currently still open for discussion. It requires a more complete understanding of accessibility than traditional indicators offer, and also depends on the theory of justice used.

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