A METHODOLOGY TO ASSES THE CONTRIBUTION OF THE LAND USE
AND TRANSPORT SYSTEMS TO SUSTAINABLE URBAN MOBILITY.

Cecília Silva
CITTA – Research Centre for Territory, Transports and Environment;
Faculty of Engineering of the University of Oporto
PhD Scholarship from the FCT – Fundação para a Ciência e Tecnologia

Paulo Pinho
CITTA – Research Centre for Territory, Transports and Environment;
Faculty of Engineering of the University of Oporto

1. ABSTRACT

The deterioration of urban mobility conditions, which have been threatening the quality of life and the competitiveness of urban areas, has lead to the recognisance of the need to strive for sustainability in urban mobility patterns. The integration of land use and transport policies has been frequently pointed out as a potential contribution for more sustainable mobility patterns. Nevertheless, in spite of the broad political and academic recognition for the need to integrate land use and transport policies to foster more sustainable mobility patterns, such integration is seldom put into practice. This can be imputed, in part, to the lack of policy design support tools for policy integration, in contrast to the abundance of tools for comparison of alternative policy strategies.

The aim of this paper is to present a methodology of analysis – using cumulative opportunities accessibility measures – of the potential of land use and transport systems to give the necessary conditions for sustainable passenger mobility patterns in urban areas. Furthermore, the potentials and limitations of this methodology will be discussed.

2. INTRODUCTION

Urban mobility problems, such as traffic congestion, have been threatening the quality of life and the competitiveness of urban areas as well as their sustainable development. In this respect, the European Commission has identified the following two main requirements for mobility management: reduction of travel needs and making remaining travel more sustainable. However, these requirements go well beyond the normal scope of transport planning. The integration of land use and transport policies has been recognised as a more effective approach to meeting these requirements (in accordance with this idea are authors such as, e.g. Banister, 1994a,b; ISIS, 1999; Wegner and Fürst, 1999; Stead, 2003; Cervero 2003, Bertolini et al, 2005). Within a variety of constraints and motivations for travel behaviour, the land use and transport systems clearly provide the baseline exogenous conditions steering travel patterns. As a result, integrated land use and
transport policies can give the necessary (even though not sufficient) conditions for sustainable mobility patterns. Without these, complementary policy action, on fields such as economy and social behaviour, would have limited to no effect.

In spite of the theoretical and empirical evidences of the interaction of land use and transport systems and their combined effect on mobility patterns, and of the broad political and academic recognition for the need to integrate land use and transport policies to foster more sustainable mobility patterns, such integration is seldom put into practice.

This paper is part of a broader on-going research project aiming at contributing to the implementation of integrated land use and transport policies for urban mobility management. The lack of design-support tools is pointed out as one of the reasons for the scarce translation of rhetoric and theory of integrated land use and transport policies into practice (Bertolini et al, 2005; Straatemeier, 2006).

Authors, such as, Handy and Neimeier (1997), Halden et al (2000), Halden (2002) and Bertolini et al (2005) suggest that the concept of accessibility can be a useful framework for the design of integrated land use and transport policies, since it comprises characteristics of both systems. Geurs and Wee (2004) believe accessibility to be a good measure of land use and transport policy because of its ease of interpretation and operationalisation. Additionally, Makri (2001) suggests that this concept can be regarded as a measure of the potential sustainability of built environment as well as of quality of life, in contrast to normative ideal types of urban structure which rigidly define urban form. Nevertheless, Bertolini et al (2005; pp.209-210) state that although accessibility measures have long been used in the academic and planning debate, “[…] the translation of such concepts in performance measures that can be usefully employed to improve integration of transport and land use plan making in practice is still very limited (Handy and Neimeier, 1997; Geurs and van Wee, 2004)”. Therefore there is a need to introduce accessibility measures into policy design contributing to the development of performance measures. These need to be theoretically sound as well as simple, plain and easy to understand, to ensure their use in practice.

With this purpose, this paper proposes a methodology for the analysis of the potential of the land use and transport system to provide the necessary conditions for sustainable urban mobility patterns which may also be used as a tool for identifying integrated land use and transport policies for urban mobility. This methodology resorts to cumulative opportunities accessibility measures.

The following two sections briefly present a review of the debate on the land use and the transport factors influencing travel behaviour and on the concepts and measures of accessibility. Section 5 presents the methodology of analysis and discusses the main underlying choices. Finally, the last section develops an ex-ante evaluation of the potentials and limitations of this methodology.
3. MAIN FACTORS INFLUENCING URBAN MOBILITY PATTERNS

Within the research theme, only land use and transport factors will be considered within all reasons underlying trip-making. Consequently, the research target of travel will be constrained to ‘derived demand’, which can directly be related to the settings provided by land use and transport systems. Within this context mobility patterns are believed to result form the need to participate in geographically disperse activities provided by the land use system and given access by the transport system.

Figure 1 presents a conceptual framework of the main land use and transport system factors, as well as constraints, likely to influence travel patterns. The scheme summarizes the main conclusion of the literature review on empirical evidence of the referred influence.

Although it is fair to say that within the research field of the influence of land use on travel patterns most authors believe that land use has influence on travel behaviour, no consensus is to be found on the main land use factors influencing travel patterns. Even in the absence of a consensus, Density, Diversity and Design stand out from the analysed land use factors, not only for being frequently considered in this research field but mainly for being those for which most frequently influence on mobility patterns could be found. These three factors are called by Cervero and Kockelman (1997) as the 3D’s of land use influence on travel behaviour. It seems reasonable to consider density, diversity and design as the potential main factors of land use influencing travel behaviour. Nevertheless, other land use characteristics, such as, proximity to urban centres, settlement size, job-housing balance, provision of local facilities and services were also considered in empirical studies on the influence of land use on urban mobility, an in some cases found to be relevant.

Studies evaluating the main factors of transport system influencing travel choice are hard to find. It is reasonable to believe that the influence of the transport system is considered as a fact. Aware of these limitations but also of the importance of understanding the main factors influencing travel behaviour,
these were identified within the main transport system aspects on which current TDM policy measures (considering transport measures) act. This was based on the assumption that those aspects are the characteristics of the transport system with the most important influence on travel behaviour. Considering this, the main transport system factors influencing travel patterns could be summarised as: Service level or Quality, Availability and Price. Service level or Quality referring to, for instance, the capacity of every transport mode and the quality of that service including, for example, speed, reliability and flexibility, road construction quality, available services, ticket technology, comfort and security. With Availability we refer to, for instance, the existence of a viable transport option for the required travel pattern, within a viable access distance. The Price refers, naturally, to the monetary cost of purchase of the transport service.

The literature reviewed enabled the identification of travel cost (Meyer, 1999, Boarnet and Crane, 2001, Cervero, 2002; Gärling et al, 2002; and Wee, 2002), travel time (Cervero, 2002; Gärling et al, 2002; and Wee, 2002) and features of travel convenience (Gärling et al, 2002; and Wee, 2002) as the main constrains of travel behaviour choice. Each potential travel behaviour choice, influenced by land use and transport system factors, and characterised by a particular set of travel distance, time, frequency and used mode (main mobility indicators, as defined by Bovy et al, 1993), can be compared for their potential constraints leading to the choice of a particular travel behaviour.

4. ACCESSIBILITY: CONCEPT AND MEASURES

In spite of the believe that the concept of accessibility can be a useful framework for the design of integrated land use and transport policies no universally used definition of this concept can be found in the literature. According to Gould (1969, p.64; cited in Ingram, 1971) “Accessibility … is a slippery notion … one of those common terms that everyone uses until faced with the problem of defining and measuring it”. In contrast to the notion of mobility, commonly related to the ‘ease of movement’ which can easily be operationalised, accessibility is commonly related to the ‘ease of reach of desired opportunities’ (Levine & Grab, 2002). Accessibility has a far more ambiguous notion, implying a range of aspects such as, the distribution of potential destinations; the magnitude, quality and character of activities; the performance of the transportation system; characteristics of the individuals; and the times at which the individuals are able to participate in activities (Handy and Niemeier, 1997; Liu and Zhu, 2004).

According to Handy and Neimeier (1997) and Halden (2002), the concept of accessibility is based on the notion that travel is ‘derived demand’. It is therefore appropriate for the purpose of this research and for the methodology presented in this paper.

Authors such as Geurs & Eck, 2001 argue that the definition of the concept of accessibility depends on the objective for which it is intended. Nevertheless,
the definition of accessibility for operational purposes, such as the use in the
design of integrated land use and transport policies, is of the utmost
importance for its effectiveness as policy instrument. Within this context, it is
fair to say that, although there is no consensus on the definition of
accessibility, nor one best accessibility measure (which translates the
accessibility concept into the operational measure), this must not be regarded
as a problem. Furthermore, this variability can be regarded as a potential for
the use of accessibility as policy indicator because of its adaptability to
different objectives.

Within this context, the choices to be
made for the definition of accessibility
measures should be in accordance to
research objectives and the particular
situation. These could be summarized
as the choices of:
− the type of accessibility measure;
− the operational detail for the
  accessibility measure;
− the components used.
These choices are interdependent and
mutually influencing, combining
themselves into the final definition of
the operational accessibility measure
(see Figure 2).

**Figure 2:** Choices for accessibility
measures

The variety of **accessibility measures** currently known can be grouped into
the following main categories (based on the main categories defined by Geurs
and Eck, 2001):

− **Infrastructure-based accessibility measures** measure the transport
infrastructure performance (example of indicator used: average speed on
road network);
− **Activity-based accessibility measures** are based on the availability of
opportunities to satisfy individual needs, their spatial distribution and the
impedance of travel (example of indicator used: number of activities within
a maximum distance);
− **Utility-based accessibility measures** are based on utility theory and
measures the benefits individual may drive form the land use and
transport system.

Although there is no one best measure of accessibility there is a general
understanding on the main **components of accessibility measures**. According to Handy and Neimeier (1997) and Stanilov (2003), measures of
accessibility generally consist of two parts, the activity component (or the
motivational or attraction component) and the transport component (or the
resistance or impedance component). Other authors include two further
components of accessibility measures. Geurs and Eck (2001) and Geurs and
Wee (2004) argue the importance of considering temporal and individual
components in accessibility measures. Nevertheless, these authors recognize that it would be difficult to consider all four components in accessibility measures since it would imply high levels of complexity.

With regard to the operational details of the accessibility measure, the type of opportunities considered, the distance decay function, and the demarcation of the research area, for instance, are some examples of further particular choices required (Halden et al, 2000).

4.1 The Accessibility Measure: Cumulative opportunities

Cumulative opportunity measures are one of the simplest activity-based accessibility measures measuring either, the number of opportunities reachable within a given travel time, distance or cost, or, the average travel time, distance or cost required to reach a fixed number of opportunities. This measure does not consider the loss of accessibility with the increase of distance from the destination to the origin. For this measure a cut-off value must be chosen, identifying the theoretical limit for admissible conditions of accessibility.

Geurs and Eck (2001) and Geurs and Wee (2004) highlighted the ease of interpretability and of communicability (easy to explain/understand) and therefore to operationalise as well as the ready availability of required data as the main advantages of this accessibility measures. The same authors point out the following main disadvantages: the lack of consideration of loss of accessibility with travel distance; the lack of consideration of the divergent desirability of opportunities with distance and type; the arbitrary selection of admissible accessibility limits; and the lack of consideration of competition effect (at origin and/or destination); and the lack of consideration of the combined effect of land use and transport.

5. METHODOLOGY OF ANALYSIS

This section presents the proposed methodology of analysis of the sustainability of the land use and transport systems. Considering the research goals of the broader research study within which this methodology is enclosed, the purposes of the referred methodology are twofold:

- Analyse of the present contribution of land use and transport systems to the sustainability of urban mobility patterns;
- Serve as a decision-support tool for mobility policies aiming for sustainability.

Therefore, the methodology of analysis presented in this section is, firstly, expected to analyse if the land use and transport system present the necessary characteristics (necessary but not necessarily sufficient characteristics) to enable sustainable mobility patterns. Nevertheless, effective mobility patterns may not live up to the created conditions by the urban system due to the influence of other mobility factors. This first purpose
is by itself a useful tool for local authorities to enhance their knowledge of the
urban system aspects conditioning mobility patterns. Furthermore, this
methodology can be used as a decision-support tool for mobility policies,
identifying in an inverse process, the urban system aspects for which changes
must be introduced (as well as the extend of the necessary change) to deliver
the desired urban structure conditions for more sustainable urban mobility.
Besides of being a decision-support tool it may also be used for public
information to justify political decision for policy measures with low public
acceptability.

It is important to point out that this methodology does not measure mobility it
self, neither its sustainability, it rather measures the extent to which the urban
systems (land use and transport systems) give the necessary conditions to
enable sustainable mobility patterns. Furthermore, four main constraints for
the use of the proposed methodology of analysis must be named:
− this methodology is adapted for the study at meso-scale (approximately
the metropolitan scale) not considering micro-scale issues such as the
influence of aspect of urban design on mobility patterns;
− this methodology requires a study area presenting mainly internal travel
(only residual cross, entry and exit travel patterns may be present);
− this methodology requires data of population, employment and activities
(divided by type) for considerably small sub-regions (a high disaggregation
level of statistical data, ideally at census tracks, is required);
− this methodology requires the definition of a study boundary which is
sufficiently wide to avoid artificial reduction of accessibility values of the
study area sub-regions due to proximity to the limits of the area.

The following scheme represents the conceptual framework for the operation
of the proposed methodology of analysis within, both the analysis of urban
system (continuous arrows) and the identification of integrated land use and
transport policy options conditioned by policy strategies for sustainable
mobility (dashed arrows).

**Figure 3:** Conceptual framework of the methodology of analysis
The direct use of the methodology of analysis gives an understanding of the contribution of the land use and transport system to the sustainability of urban mobility patterns. This knowledge constitutes the baseline for the development of the strategy for the improvement of sustainability concerning urban mobility patterns. This strategy can then be translated into land use and transport action options, resulting from the inverse use of the methodology of analysis. Besides the identification of the action fields, the extent of the necessary action on those fields (giving answer to required improvements in sustainability) can also be found in the process. The choice of the policy package to be implemented, within the identified action options, becomes a purely political decision. This choice is based on the political strategy defined as well as on the constraints for implementation of alternative policy action (such as financial, physical, political, or social constraints).

![Objective tree of the methodology of analysis](image)

**Figure 4:** Objective tree of the methodology of analysis

The methodology of analysis develops on three main strings, based on the three main operational objectives for the land use and transport system (see hierarchy of objectives in Figure 4): to encourage short distance travel, to be public-transport friendly and to hinder unnecessary, long distance and frequent travel by car. These three objectives are closely related to 3 distinct categories of distance and transport mode (two of the main mobility indicators defined by Bovy et al, 1993). The first objective is related to the use of non-motorized modes and short distance travel; the second objective relates to the use of public-transport and to medium distance travel; the last objective is related to the use of the car and long distance travel.

For the evaluation of the contribution of the land use and transport system to the three operational objective outlined, the criteria of accessibility was chosen (see Figure 5) in accordance with authors such as Handy and Neimeier (1997), Halden et al (2000), Halden (2002) and Bertolini et al (2005) who believe accessibility to be a useful framework for the design of integrated land use and transport policies. Taking into consideration the aim of this research the choice of the type of accessibility measure fell upon the
cumulative opportunity accessibility measure, a type of activity-based measure. The choice of this type of measure is related to its main advantages (as presented in the previous section). Both, the ease of interpretability and of communicability of this measure and the ready availability of required data are of the utmost importance for the purposes of the presented methodology. Considering the two main purposes of the methodology of analysis, the availability of necessary data and the interpretability and communicability of the measure, are naturally fundamental aspects of this measure. In accordance with authors such as Pirie (1981), Geurs and Eck (2001), Makrí (2001), Stanilov (2003) and Bertolini et al (2005), we believe that its loss in comprising more complex issues such as, the decline of accessibility with distance and competition effect (at origin and destination), are clearly compensated by the ease of operationalisation of these measures into policy design tools (enabled by both its main advantages)\(^5\).

From the four components of accessibility measures defended by Geurs and Eck (2001) as important to be considered in accessibility measures, the cumulative opportunity accessibility measure used for this methodology, only considers the transport and the activity components. This choice stands on the main objectives and purposes of the proposed methodology of analysis.

Within the described conditions, from the main land use and transport factors influencing travel behaviour (see Figure 1) the developed accessibility measure considers: service level, availability and price of the transport system (mainly present as cut-off aspect); and density and diversity of the land use system (which are the opportunities and their distribution counted by the accessibility measure)\(^6\).

For this methodology the measure of accessibility was disaggregated by three levels: geographical scale (dividing into regions and sub-regions), trip purpose (dividing into reach of population, employment and diversity of activities) and mode (dividing into non-motorized modes, public transport and the private car). Furthermore, several cut-off measures are used for each accessibility measure (see aspects considered for accessibility measure and cut-off values in Figure 5).
Methodology of Analysis

**Sustainability indicators evaluated**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-motorized modes (NM)</td>
<td>Short-distance</td>
</tr>
<tr>
<td>Public transport (PT)</td>
<td>Medium-distance</td>
</tr>
<tr>
<td>Car (Car)</td>
<td>Long-distance</td>
</tr>
</tbody>
</table>

**Analysis Criteria**

- **Cut-off's:**
  - TT<20min; R<1.5
  - TT+WT<45min (30 min PT [include half of headway as average WT]+15 NM to and from PT); WT inter.<5min ∆TP(interchange)>0 X<3
  - TT<30min; TP?<=(TD*[PP+PM]+PT+PPk) R<2

**Accessibility (measure: cumulative opportunities measure)**

- **Accessible Population - AccP**
  - NMAccP
  - PTAccP
  - CarAccP
- **Accessible Employment - AccE**
  - NMAccE
  - PTAccE
  - CarAccE
- **Accessible Diversity of Activities - AccDiv**
  - NMAccDiv
  - PTAccDiv
  - CarAccDiv

**Classification of accessibility values:**
- A - High
- B - Medium
- C - Low

**Results for each territorial unit:**
- classification for each trip purpose of the comparative accessibility by each mode:
- (NM; PT; Car) according to the scale of classification of accessibility values (A, B and C)
- e.g. Population (B, B, A)
- Employment (C, B, A)
- Activities (B, A, B)

©Association for European Transport and contributors 2006
The application of the presented methodology is based on two main considerations:

- sub-regions may be considered homogeneous;
- the central point of the sub-region is an appropriate representation of the entire sub-region (considering the measure of accessibility).

These considerations are based on the constraint, for the use of the proposed methodology, that data of population, employment and activities (divided by type) is available for high spatial disaggregation (ideally census tracks). This enables the disaggregation of the study region into very small sub-regions.

Within these considerations, the centres of all sub-regions form a representative sample of all potential origins of the region in analysis. Consequently, accessibility for each sub-region can be determined for the geometrical centre. Furthermore, it seems acceptable to consider regional accessibility as the simple average of sub-regional accessibility. Since the same concept of accessibility measure is used on the same origin points for different transport modes, this accessibility measure enables the direct comparison between different transport modes (and subsequently between different reachable travel distances). As a result, evaluating accessibility mainly consists of the determination of the accessible area for each theoretical point of origin, and for these accessible areas determine the quantity of population and employment, and the diversity of activities which are reachable. As the values of population, employment and activities are considered homogeneous within sub-regions (only valid for high spatial disaggregation), opportunities in reach (within the boundaries of the accessible area) are proportional to the area of each subsection in reach.

Aiming to increase its understanding and operationalisation for policy design, these simplifications of the reality seem reasonable within the purpose of the methodology.

This methodology comprises the calculation of nine accessibility indicators for each spatial unit, resulting of the disaggregation of the accessibility measure into usable transport modes and trip purposes. The methodology may be further subdivided into several types of activities enhancing its potential analysis of trip purposes.

Table 1 summarizes the main accessibility indicators used in this methodology, disaggregated by spatial scale and trip purpose. Besides of the absolute values of accessibility for each indicator, relative value will be used for accessibility to population and employment. This option enables a comparative evaluation of accessibility measures in stead of an absolute one. With regard to accessibility concepts, this is fare more interesting, considering the low significance of absolute values of cumulative opportunities measures.
Table 1: Accessibility indicators used

<table>
<thead>
<tr>
<th>Trip purpose (access to...)</th>
<th>Spatial unit</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>$Acc_{P_i} = \sum_{i'} P_{i0} \cdot \sum_{i'} \left( P_{i'} \cdot A_{i0} / A_i \right)$ [1]</td>
<td>$AccP = \frac{\sum_{i'} Acc_{P_{i'}}}{P}$ [3]</td>
</tr>
<tr>
<td></td>
<td>$RAcc_{P_{i'}} = \frac{Acc_{P_{i'}} \cdot 100}{AccP}$ [2]</td>
<td>$AccP(%) = \frac{AccP \cdot 100}{P}$ [4]</td>
</tr>
<tr>
<td>Employment</td>
<td>$Acc_{E_i} = \sum_{i'} E_{i0} \cdot \sum_{i'} \left( E_{i'} \cdot A_{i0} / A_i \right)$ [5]</td>
<td>$AccE = \frac{\sum_{i'} Acc_{E_{i'}}}{E}$ [7]</td>
</tr>
<tr>
<td></td>
<td>$RAcc_{E_{i'}} = \frac{Acc_{E_{i'}} \cdot 100}{AccE}$ [6]</td>
<td>$AccE(%) = \frac{AccE \cdot 100}{E}$ [8]</td>
</tr>
<tr>
<td>Diversity of activities</td>
<td>$AccDiv_i = \frac{NA_i}{TNA}$ [9]</td>
<td>$AccDiv = \frac{\sum_{i'} AccDiv_{i'}}{TNA}$ [10]</td>
</tr>
</tbody>
</table>

where:
- Acc – accessibility to a given opportunity (P – number of population, E – number of employment, Div – diversity of activities)
- RAnc – relative accessibility
- $i'$ – spatial unit which is an accessible destinations from i
- $A_{i0}$ – area of the spatial unit i which is an accessible destinations from i
- $P_{i0}$ and $E_{i0}$ – proportion of population / employment that is within $A_{i0}$
- $NA_i$ – number of types of activities accessible from i (weighted by frequency of use)
- TNA – total number of types of activities considered

For the analysis of the results of the methodology each accessibility indicators will be classified into a three folded scale (see Figure 5):
- A for high value of accessibility to opportunities;
- B for medium value of accessibility to opportunities;
- and C for low value of accessibility to opportunities.

For sub-regions relative values of accessibility will be used while, for the region as a whole, absolute values will be used to define the classification. The accessibility for each territorial unit and trip purpose can be classified using a combination of accessibility classes for each transport mode represented as follows: “(NM, PT, Car)”, for ‘NM’, ‘PT’ and ‘Car’ being filled with the classification of accessibility by non-motorized modes, public transport and the car, respectively (for an example see Figure 5). Finally, each territorial unit will be classified by three combinations of accessibility classification (one for each trip purpose). The use of broad classes for the classification of accessibility enables the benchmarking of the sub-region and the region according to the contribution of its land use and transport system for sustainable mobility pattern. The Benchmarking scheme for the evaluation of the sub-regions and regional accessibility is presented below. Each region will have one evaluations of A’s, B’s and C’s with 27 combinations of possible evaluations. Accordingly, each territorial unit will have three locations in the benchmarking cube.
Benchmarking (and its schematisation – see Figure 6) gives an outstanding policy support tool aiding the choice of policy strategies through the development of a scale which can cope with the lack of ability to quantify sustainability improvement objectives. It does so by providing a 3 dimensional scale enabling comparison of the relative performance of the major groups of transport modes (for each trip purpose). This relative performance classifies the contribution for sustainability of the urban system which can be directly related to the conditions of the land use and transport systems of that urban area. Therefore, the definition of mobility strategies would be equivalent to identifying the change of the position of the accessibility indexes within the benchmarking cube. This comparative and benchmarked methodology of interpretation of the results holds many of the potentials of the proposed methodology of analysis which will be further discussed in the next section.

6. DISCUSSION

Taking into consideration that this methodology has not yet been tested, this last section aims to develop a discussion of the believed potentials and limitations of this methodology. Therefore, we chose to limit this ex-ante evaluation of the methodology to the discussion of the balance between soundness and plainness of the proposed methodology (within other relevant evaluation criteria). This evaluation aims to anticipate the main operational and theoretical advantages and disadvantages as well as to summarize the expected potential and the identified limitations of the methodology presented in the previous section.

According to Betolini et al (2005; 218) “A major methodological challenge when working with accessibility measures in land use and transport planning is finding the right balance between a measure that is theoretically and empirically sound and one that is sufficiently plain to be usefully employed in interactive, creative plan-making processes where participants typically have different degrees and types of expertises”.

©Association for European Transport and contributors 2006
The main aspect contributing for the balance between soundness and plainness of the methodology of the analysis proposed are presented in Figure 7. We chose a simple measure of accessibility – the cumulative opportunities accessibility measure – with regard of the two main purposes of the methodology which clearly set requirements for an easy operationalisation and communicability. Two further operational simplifications are introduced by the use of a limited number of origin points representing the accessibility along the region and by considering the regional accessibility being considered as the average of sub-regional accessibilities. These simplifications contributed for the plainness of the developed methodology improving its operationalisation while, at the same time, reducing its soundness.

In order to minimize the losses of accuracy of the methodology, soundness was enhanced through the consideration of high levels of spatial disaggregation, through the considerable disaggregation of the accessibility measure used (by mode and trip purpose) and through the high detail of cut-off values. On the one hand, high spatial disaggregation enhances the consistency of the measure for the use of a limited number of origin points in stead of all potential origin points. On the other hand, the disaggregation of the accessibility measure by mode enables the development of comparable values across modes and land use characteristics, enabling the analysis and understanding of combined effects of the land use and transport systems (one of the main disadvantages of this type of accessibility measure and indispensable for the development of integrated land use and transport policies)\(^{14}\). Together with the disaggregation by trip purpose and the consideration of further detail for cut-off values, these aspects of the accessibility measure contributed for the enhancement of the soundness of the methodology and the consistency of its measures.

Considering the disaggregation by trip purpose, further accuracy was introduces by the consideration of diversity in stead of quantity for the accessibility to activities. It seems reasonable to consider the number of types of accessible activities to have a higher influence on travel behaviour than the global number of activities. The index of accessibility to diversity of activities (based on the dissimilarity index from Cervero and Kockelman, 1997) calculates the ratio between the number of accessible types of activities and the total number of activities considered to have the highest influence on travel behaviour\(^{15}\).

Further detail for cut-off values was introduced by accounting for the availability of transport modes, the connectivity of the public transport network, the directness of path for non-motorized and car travel and travel cost (besides of traditional travel time issues). In addition, precision in the definition of accessibility boundaries was increased through the combination of several of the referred aspect and through the use of more complex definitions of each aspect (see cut-off aspect purposed for each transport mode in Figure 5\(^{16}\)).
The strive for increased soundness of the methodology, besides of producing more complex results (wide range of indicators for each sub-region), resulted in a more demanding methodology, for both, statistical and geographical data, at the same time as it involves more complexity in the calculation of results (although this complexity can be managed resorting to programming). Nevertheless, the increased complexity introduced by these aspects required further action to compensate operationalisation and communicability of the methodology. This was managed by benchmarking the results of the methodology in a few comparable scales of classification and through the use of relative in stead of absolute measures of accessibility for sub-regions. The high disaggregation of the measure of accessibility added to the use of a scale of classification of the values of accessibility enables the comparability of results and enlarges the potential of the methodology for identification and interpretation of the land use and transport system influence on mobility patterns.

### Figure 7: Balance between soundness and plainness of the methodology

<table>
<thead>
<tr>
<th>Plainness</th>
<th>Soundness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of simple measure of accessibility (resort to cut-off values for admissible accessibility)</td>
<td>High spatial disaggregation</td>
</tr>
<tr>
<td>Accessibility measured for a limited amount of origin points (representative of sub-regions)</td>
<td>High disaggregation of accessibility indicators</td>
</tr>
<tr>
<td>Accessibility of region defined as average of sub-regions</td>
<td>High detail for cut-off values</td>
</tr>
<tr>
<td>Use of relative in stead of absolute values of accessibility for sub-regions</td>
<td></td>
</tr>
<tr>
<td>Benchmarking of results</td>
<td></td>
</tr>
</tbody>
</table>

The aspects presented in Figure 7 summarize the main improvements introduced during the development of this methodology to plain cumulative opportunities measures. The underlying idea was to introduce more complexity and accuracy in auxiliary aspect of the measure of accessibility maintaining the measure itself, simple, easy to understand and communicate.

In an attempt to anticipate the implementation of the methodology, the main advantages and disadvantages (or operational problems) could be summarized as follows.

**Advantages:**
- use of a simple accessibility measure;
- use of few statistical data, which are generally available;
- ease of interpretability and communicability of results and conceptual model of methodology;
consideration of combined effect of land use and transport systems

Disadvantages (main problems which may be found when trying to use the methodology):
- requires availability of highly spatial disaggregated statistical data;
- requires the availability of detailed geographical data (sidewalk network; public transport network including travel speed and headways; road network including travel speed, traffic direction and forbidden turns).

In conclusion, although this methodology has not yet been tested, considering the analysis developed during this paper, we believe that the methodology of analysis has the potential to live up to the purposes for which it was created. Therefore, we argue that the main potentials of this methodology are:
- to be useful in the understanding of the conditions given by the land use and transport system of an urban area for the sustainability of passenger mobility patterns – through the analysis of the combined influence of land use and transport on the potential use of different transport modes and the need to engage in different travel distances to reach desire opportunities.
- to be useful for the definition of strategies to enhance sustainability (coping with the lack of ability to quantify sustainability improvement objectives) and for the definition of alternative integrate land use and transport policy actions as well as their range.

Nevertheless, several limitations can be point out for this methodology:
- does not consider competition effects;
- does not consider temporal and individual components of accessibility measures;
- does not consider decrease of accessibility with distance;
- does not consider other important criteria besides of accessibility, such the availability of car parking or the relative availability of car parking within and outside public transport use range ;
- uses only a sample of origin points for the measure of accessibility.

The major limitation of this methodology is related to the fact that it does not consider local public administration borders. Although this is clearly an advantage since urban mobility does not consider them as well, as policy action will be of the responsibility of local authorities the use and consideration for policy purposes of the methodology presented in this paper would be dependent of institutional arrangements across municipalities which are difficult to establish.

7. ACKNOWLEDGEMENTS

This research was financed by the Foundation for Science and for Technology (‘Fundação para a ciência e para a Tecnologia’ - FCT).
The development of the methodology has taken advantage of the suggestions resulting of a presentation at the PhD workshop of the AMIDSt conference, entitled “Transportation Planning a Policy Design Challenge?” (Amsterdam,
2006). Worth pointing out was the contribution of Franc le Clercq and Perry Hoetjes to the development of the benchmarking tool.

### 8. BIBLIOGRAPHY


©Association for European Transport and contributors 2006


Consequently, in spite of the awareness of their existence, motivational factors found in the literature review, such as, preferences (Schlich et al 2004; Scheiner & Kasper, 2002), value orientation (Scheiner & Kasper, 2002), need and desires, and symbolic affective motives (Steg et al, 2001), habits (Fuji & Gärling, 2003; Gärling & Axhausen, 2003; Fuji & Kitamura, 2003), beliefs and attitudes (Fuji & Kitamura, 2003) as well as the concepts of undirected and excess travel (Mokltharian & Salomon, 2001), will not be considered.

For further detail of the conceptual framework and of the literature review of the factors influencing mobility patterns see Silva and Pinho, 2005 (including household/individual factors besides of land use and transport factors).

In agreement with Gärling et al (2002) who suggest that the classification of TDM measures is a promising mean for understanding potential reasons for behavioural change or lack thereof.

Also highlighted by Bertolini et al (2005).

Nevertheless, it is important to highlight that several improvements (based on other accessibility measure types) were introduced to the basic formulation of cumulative opportunities accessibility measures, reducing some of its disadvantages and increasing the accuracy of the measure. For further detail see section 6 — analysis of the balance between soundness and plainness.

Taking into consideration that the methodology of analysis is adapted for the study at meso-scale the consideration of the design land use factor, which if conceptually a micro-scale factors, was considered inappropriate.

Within the land use factors influencing travel behaviour, density and diversity, the consideration of the number of types of accessible activities is more adequate choice since it has higher influence on travel behaviour than the global number of activities.

Disaggregation by mode is not necessary for the presentation of the general formula of accessibility indexes since the concept of accessibility used is the same for all transport modes.

The relative value of accessibility is the ratio between the absolute sub-region accessibility and the absolute regional accessibility.

No relative values for indicators of accessibility to diversity of activities are used because the main indicator is already a relative value by it self.

The complete definition of the boundaries for each classification are not yet consolidated and will therefore not be discussed in this paper.

Since the research project within which it is included is currently in the process of preparing implementation of the methodology.

This authors define soundness as the “consistency of measures with the behaviour of households and firms” and plainness as the “transparency of computing procedures and ease of calculations—or the communicative qualities of the measures” (Bertolini et al, 2005; 218).

This is possible because these indicators simultaneously evaluate land use opportunities available and enable the comparison of the accessibility to these opportunities across available transport modes.

Some examples of the considered types of activities are leisure, such, shopping, public services and health care.

The values presented in Figure 5 are only indicative and will be adjusted further on in the research.