International Transport Forum

Improving Transport Planning and Investment Through the Use of Accessibility Indicators

Case-Specific Policy Analysis

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The International Transport Forum

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Executive Summary

Background

Generating adequate access to opportunities is a fundamental condition for ensuring well-being. Yet, many transport policies are still more focused on generating physical movement and increasing speeds than in guaranteeing access. This has often resulted in induced demand (i.e. the phenomenon that increasing road capacity leads to an increase in traffic volumes), exacerbating congestion, pollution and greenhouse gas emissions. A focus on private motorised transport also tends to exacerbate inequality and social exclusion. By shifting the focus of policies and investment from accommodating traffic growth to improving accessibility authorities could deliver simultaneously on a wide set of sustainability goals.

The development of accessibility indicators and their inclusion in policy and decision-making frameworks is key to moving in this direction. These tools can help increase authorities' capacity to track effectiveness of transport and urban development policies in terms of the accessibility delivered and to prioritise investment in a way that is coherent with enhancing access to opportunities, especially for vulnerable groups. In sum, these tools are key to effective accessibility-based policy, planning and investment frameworks in which accessibility considerations systematically guide decisions.

The ITF is working with the European Commission to develop accessibility indicators for benchmarking cities in terms of the way they deliver access across the functional urban area. As part of this effort a workshop was convened in 2018 on "Improving Transport Planning and Investment through the Use of Accessibility Indices" for stakeholders and experts to share their experience in developing operational accessibility indicators. The results are summarised in this report.

Findings

The term accessibility has become more present in the political discourse; however, it has been regularly misinterpreted or poorly defined. Accessibility is often used without a definition or as a synonym for mobility. This reinforces policies that biases towards car-oriented planning by favouring physical movement, while ignoring the role of land-use policies in improving access. Careful and consistent use of the term accessibility is important if there is to be a shift in policy making.

Accessibility ultimately contributes to the broader objectives of greater well-being and sustainability; however, many of the factors that contribute to well-being sit largely outside of those traditionally accounted for in transport project assessments. What's more, the role of different transport modes in increasing access for different groups at different territorial scales is often poorly understood. Indicators that can be used to compare the quality of access delivered by different transport modes, at different territorial scales and for distinct populations, are needed to link decisions solidly to an accessibility-based policy framework. Such indicators are also valuable for benchmarking accessibility and comparing cities' performance, delivering insights to guide decisions on investments at different territorial scales.

Recommendations

Improve understanding of links between changes in accessibility and well-being

Transport can contribute more effectively to wider well-being objectives if potential synergies between improving access to opportunities and such goals as reducing pollution, curtailing greenhouse gas emissions, limiting social exclusion and improving health are considered. For this, it will help to further explore and quantify how providing accessibility through different transport modes plays out in terms of ultimate sustainable mobility outcomes. Combining data on quality of access to opportunities by different modes with data on income distribution can shed light on ways to address income inequality. Similarly, analysing links between transport accessibility and emissions from the transport sector will increase understanding of how changes in proximity of activities and in the relative performance of different modes can lead to better environmental outcomes.

Analyse local accessibility needs rather than focusing on the regional scale

Accessibility needs should be considered at a neighbourhood scale and for different population groups when making planning and investment decisions. Analysing accessibility only at regional scale generally creates a bias for options yielding the maximum distance reachable via the fastest mode, and authorities need to move beyond this. Analysis of accessibility needs at neighbourhood scale can better capture the importance of proximity. This is especially true for delivering accessibility improvements through slower but more sustainable modes such as walking and cycling. A local focus also helps to better identify day-to-day accessibility needs for different population groups.

Use a mix of easy-to-use indicators to support planning decisions

Developing indicators that measure each component of accessibility and then combining them according to their strengths is central to robust accessibility-based decision-making. Using a mix of indicators suited for different types of analysis and activities is preferable to trying to find a "one-fits-all" solution. To ensure accessibility indicators will be used systematically for planning purposes, researchers, planners and policy makers must be able to easily and intuitively understand and interpret them. Support tools available to all stakeholders, for instance interactive web-based visualisation tools, are one way to increase the understanding of the value of accessibility-based decision-making. Such tools can help to set common standards and make accessibility considerations a central criterion for decisions by multiple stakeholders.

Move beyond measuring availability of infrastructure to an examination of user needs

Measuring levels of access based on data from the existing network is not sufficient. Deficits in the quality of access to opportunities that different groups experience should also be identified. This requires developing methodologies for collecting qualitative information regarding satisfaction with available services, for instance, based on surveys. Such studies should aim to identify where different groups of citizens (e.g. of a certain age, occupation or gender) lack appropriate access through available transport modes. The ways in which citizens use infrastructure, particularly for pedestrians, must be examined. Collecting data on pedestrians and cyclists is an important step in developing more detailed local accessibility indicators.

Develop better methodologies for including accessibility considerations into project appraisal

Current approaches to project appraisal capture some accessibility aspects through monetised and non-monetised impacts. However, they do not usually account for wider social impacts of improved accessibility such as social inclusion. Neither can they adequately capture the impact of location changes. To ensure that accessibility is considered in transport decisions and the allocation of investments, a better understanding of ways to incorporate accessibility into the appraisal of transport projects will need to be developed. Some of the indicators discussed in this report could serve as a first step.

Introduction

Access to goods, services and jobs is the purpose of most mobility and central to transport policy. It is rarely assessed directly but its presence in political discourse has been growing. Policy and planning documents developed by national and local authorities increasingly mention accessibility as an objective. Provision of "access to safe, affordable, accessible and sustainable transport systems for all" is at the core of the United Nations (UN) Sustainable Development Goals and a central commitment under the UN New Urban Agenda (UN, 2016).

Increased interest in accessibility is the result, in part, of poor planning and investment decisions based on a "predict and provide" approach. For example, one assumes that predicted traffic growth (particularly car travel) must be provided for (by adding road capacity). This approach has inevitably resulted in more travel, exacerbated car dependency[1] and has encouraged dispersed patterns of development. The increased congestion comes at significant costs to the economy, the environment and the overall well-being of the population. Among other things, car-oriented mobility systems and sprawled urban patterns have reduced the viability of other modes, including public transport and non-motorised transport, thus significantly contributing to the exclusion of already disadvantaged population groups (Lucas, 2004). Assessing transport policies and investment through indirect measures of access, and in particular through the standard approach of travel time savings, focuses attention on motorised modes and tends to overlook the first and last legs of trips, mostly made on foot.

The consequences of the predict-provide approach have sparked awareness of the need to rethink mobility policy and investment, focusing less on increasing physical movement and instead prioritising accessibility. Simply put, the focus must be on, "the ease of people's access to goods, services and activities" (Litman, 2018). But despite growing popularity and increasing recognition of the potential benefits of an accessibility-based approach, governments face the challenge of developing accessibility-based decision-making frameworks i.e. policy, planning and investment frameworks in which accessibility considerations are central criteria systematically guiding decisions.

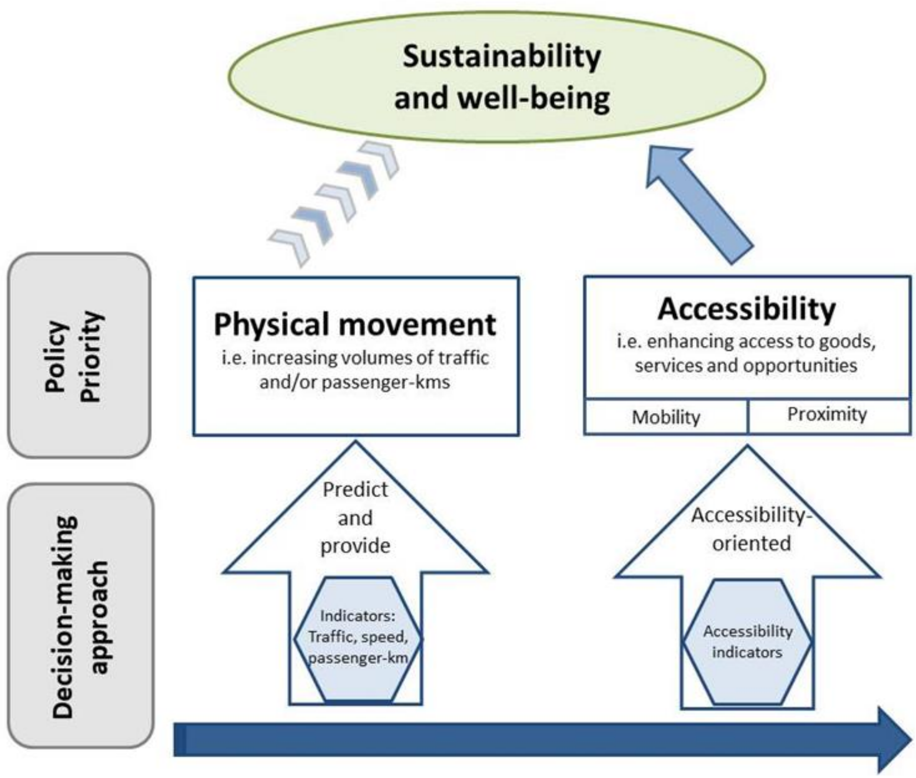
The development of accessibility indicators is a critical step in this direction. Such indicators are building blocks for accessibility-based decision-making frameworks and are central to:

- establishing accessibility as a criterion for decision-making
- providing a common language for the integration of planning and decision-making between transport and other policy areas (such as land-use development and housing) towards the common goal of enhancing accessibility
- monitoring progress in achieving accessibility goals
- comparing territories according to the access to opportunities or points of interests they offer - and thus contributing to making accessibility a central criterion for a policy success.

Focusing on accessibility instead of physical movement can shift the paradigm for mobility policy and investment. This report examines how accessibility indicators can support such a shift. Figure 1 summarises this transition and highlights the weak and imperfect link between physical movement and the objectives of overall well-being and sustainability. While higher traffic volumes certainly generate accessibility, higher movement can also reflect limited access through modes and itineraries to different activities that would require less time and money. In this sense, higher mobility volumes can result in higher congestion, greenhouse gas emissions and damage to air quality, while not necessarily improving widespread access to services, goods or activities for the population. If the focus is directly on delivering accessibility, however, the link between mobility policy and ultimate well-being as well as sustainability strengthens.

Figure 1 also shows that accessibility is the combination of mobility and proximity outcomes. An accessibility-based approach recognises the importance of public transport and non-motorised modes, as well as the role of – and need for co-ordination with – land use policy decisions (e.g. in creating location-efficient urban development[2] patterns). It can also highlight the role of mobility substitutes (e.g. home office, delivery services). These points will be further developed later in the report.

Figure 1. Paradigm shift from physical movement to accessibility



The first part of this report discusses constituent principles required for developing accessibility-based policy frameworks that can effectively guide policies towards inclusive and environmentally sustainable mobility goals. The second part provides an overview of accessibility indicator types and their utility for measuring the many components of accessibility. The final part addresses ways in which accessibility indicators have been operationalised and how they have proved valuable for multiple uses.

Ultimately, the report identifies the following priorities:

- ensuring that the term “accessibility” is clearly defined and understood by all stakeholders to avoid confusion with other terms, most specifically “mobility”)

- increasing understanding of: 1) the link between changes in accessibility and their ultimate impact on well-being and the environment; and 2) the role of various modes in achieving these goals
- making sure that accessibility concerns for different territories and scales, as well as for different population groups, are effectively incorporated into the policy agenda
- finding a mix of indicators to support and guide policy and investment decisions and develop an accessibility-oriented policy framework
- operationalising the chosen indicators by: 1) ensuring that all stakeholders can easily understand and interpret the measures; 2) developing support tools (e.g. interactive web-based tools) to increase transparency of analysis and decision-making frameworks using indicators; and 3) identifying explicit stages and mechanisms in the decision-making processes where accessibility should be a central criterion requiring such indicators.

Principles for effective accessibility-based decision-making

The link between adopting an accessibility-based approach and promoting policies to support sustainable development is strong, but not necessarily automatic. When designing an accessibility policy framework that is both relevant and effective, certain questions must be answered: What do we mean by accessibility? How much is necessary and for whom? How, or through which modes, is it to be achieved? How will the scale and specific context affect accessibility analysis? How does it align with wider policy goals for sustainable development? This section turns to literature and experts' discussions to explore these questions.

Defining desirable types of accessibility

Moving towards effective accessibility-oriented framework first requires a clear definition of the term "accessibility". The problem of the term's conceptual ambiguity in European policy making was identified during research for the COST Action "Accessibility instruments for planning practice in Europe" (Silva and Larsson, 2018). Silva and Larsson explain that "accessibility" is often used without definition or given a connotation that is quite different from the term's meaning in a transport context: the ease of reaching destinations or activities distributed in space. A common error is using "accessibility" and "mobility" interchangeably. Doing so reinforces the development of policies based on indicators focusing on physical movement. The role of land use policies is then overlooked and the bias towards car-oriented policy and planning perpetuated.

To develop useful accessibility-oriented policy frameworks authorities must clearly establish what type of accessibility is necessary to meet high-level, cross-sectoral policy goals. Central to this is identifying how actions in transport and other relevant sectors can contribute to attaining overall goals by delivering better accessibility.

In the United Kingdom, for instance, an accessibility-based approach to policy making was triggered by the government's adoption of the Social Exclusion Agenda in 2004. The Agenda's ultimate objective was to facilitate participation in economic activities by vulnerable groups. Enhancing access to employment via public transport was key. Accordingly, the Social Exclusion Unit conducted a wide-ranging study entitled "Making Connections", which focused on ways to improve accessibility to employment and vital services for people facing social exclusion. The Unit recommended using indicators to measure access to jobs and services as a way to monitor progress in improving accessibility and, in turn, reducing social exclusion. Its recommendations fed into a national action plan developed under the Social Exclusion Agenda. The plan implemented a new framework for local accessibility assessment and introduced a requirement to assess local needs against a set of indicators defined by the government. The framework helped the government ensure that local planning decisions were consistent with national goals for reducing transport-related social exclusion. (Bradshaw and Bennet, 2004)

Understanding accessibility needs for different users

It is important to understand how much accessibility is needed, relative to specific contexts and user types. Promoting wider well-being objectives requires shifting away from a mind-set that seeks "as much accessibility as possible" – often associated with blindly promoting the fastest modes – and towards identifying actual demand for accessibility. For this, accessibility-based analysis must look beyond measuring levels of accessibility being delivered (based on data from the existing network) and aim to identify the minimum level of access different groups require (Silva and Larsson, 2018).

While it is a challenging task, there are good examples of methodologies being developed to this end. Di Ciommo (2018), for instance, designed a methodology that identifies people's needs by using data from a satisfaction survey in the Metropolitan Area of Barcelona. The resulting tool, called the in-accessibility index, measures individuals' ability to reach necessary activities based on their travel time satisfaction. The goal of the analysis was to create a tool that allowed different users' needs to be taken into account when establishing planning and investment priorities, while simultaneously identifying population groups for which access was particularly poor. Further details are available in the "Accessibility indicators for planning" chapter of this paper.

A multimodal and territory-specific approach

Accessibility frameworks should pursue a multimodal approach to meet wider sustainability objectives. Silva and Larsson (2018) note that in many cases accessibility assessment focuses mostly or exclusively on accessibility by cars. This creates biases and disregards the relative competitiveness of other modes, leading to only partial implementation of an accessibility-based approach. For instance, when using accessibility measures to assess the impact of a new motorway, assessing only changes in accessibility by road will show a positive impact. However, such an assessment disregards the negative impact on public transport and the potential loss of local activities. As more remote and cheaper locations become accessible by car, there is increasing incentive to relocate. Both encourage additional car use and result in a negative overall impact on the environment.

Alternatively, measuring accessibility by different transport modes and understanding the changes in their competitiveness increases awareness of the role each plays in providing access, and their ultimate impact on sustainable mobility. Public transport, walking and cycling, for example, have proved to be more affordable for vulnerable groups. Assessing accessibility in this manner, then, will also show the social benefits related to investing in additional public transport infrastructure, thereby making these options more available and convenient. In England, a national bus pass was created in 2006 according elderly people free bus use. Initially limited to their locality, it allowed them free country-wide travel after 2008. The scheme was associated with increased active mobility (i.e. walking) and use of public transport by people aged 60 and older in an effort to increase users' quality of life through related health benefits (Coronini-Cronberg et al., 2012). Evidence also suggests that the policy has contributed to increases in access to services and inclusion in social life by people over 60 (Mackett, 2014).

In addition, new mobility services, such as ride hailing, car sharing and van pooling, provide potential bridges in accessibility gaps, particularly in peripheral areas. Cities have started to work towards adopting appropriate regulatory frameworks to accompany the development of these services. The aim is to allow these services to deliver efficiency gains along with consumer and other benefits while mitigating their potential negative impact (Deighton-Smith, 2018). Considering such options can serve an accessibility agenda.

Competitiveness of modes will be affected by the characteristics of territories (e.g. density, commuting patterns, and income). For instance, the extent to which levels of car ownership and car dependency can be reduced, as well as potential changes in relative competitiveness of alternative modes, may vary strongly depending on context. The proximity of points of interest in urban areas facilitates reaching the critical mass required to develop traditional public transport systems. By contrast, in less dense suburban or rural areas, the combination of lower density and longer distances between inhabitants and potential destinations makes it harder for local authorities to propose traditional public transport systems. In sum, accessibility-oriented decision-making frameworks need to be flexible and adaptable to the different realities found across territories, allowing for analysis, interpretation and identification of solutions that are customised for diverse existing conditions.

Focus on the neighbourhood scale

The way in which an accessibility-based policy framework guides decisions will depend partly on the scale at which one looks at accessibility. It is essential to move away from exclusively regional accessibility analysis – which generally focuses on the maximum distance reachable via the fastest mode – and also consider neighbourhood accessibility needs. Silva and Larsson (2018) argue that focusing on regional accessibility can result in local accessibility effects being disregarded and often leads to accessibility losses at the neighbourhood scale. This is because regional accessibility analysis cannot capture the importance of proximity in achieving accessibility when slower modes, such as walking and cycling, are involved.

The 2008 Dutch Multi-year Infrastructure, Spatial Planning and Transport programme studied congestion, travel speeds, service levels and travel time reliability to assess accessibility gains (Geurs, 2018). While this approach can be useful to reflect access levels at the regional scale (e.g. through the use of mass transit and other motorised modes), it fails to account for urban walking and cycling. The limited attention on slower modes can be especially problematic in contexts such as the Netherlands, where cycling has a large modal share in urban areas across the country.

In sum, using the term accessibility, accompanied by its correct meaning, and setting broad accessibility objectives that are consistent with existing policy priorities are prerequisites for developing useful accessibility-oriented policy frameworks. A multimodal approach that is flexible, adapts to differing territorial realities and looks at the needs of different users and territorial scales is required if authorities are to respond to wider social and environmental sustainability objectives. Overall, designing, choosing and implementing meaningful and useful accessibility indicators largely depends on applying the principles discussed in this section to establish an adequate frame for the use of these tools. The next chapter addresses how to do so.

Accessibility indicators: An overview

Focus on accessibility indicators by academics and researchers and increasing availability of data sources has allowed for the development of a wide variety of versions of these tools. Geurs and Ritsema van Eck (2001) break down accessibility into four components: distribution of potential activities, characteristics of the related destinations, performance of the transport system and characteristics of individuals and the times at which they wish to arrive. The ways in which indicators treat and reflect these components can influence results, conclusions and even perceptions of a given problem.

A balanced treatment of all four components is important, but quite challenging. On one hand, comprehensive indicators that aim at a detailed, equalised treatment of all four components could be extremely valuable. However, incorporating all four into a single indicator entails additional complexity and impedes practical operationalisation and communication of the metric. Experts have largely agreed that using multiple indicators that reflect different components and are customised to address different questions is necessary to guide policies and investment decisions.

Table 1. Overview of accessibility indicators

Indicator type	Description	Examples
Infrastructure-based	Indicators that quantify the observed or simulated performance of the transport system. These indicators can also potentially reflect interpersonal differences (e.g. access to public transport varying by social group).	Congestion levels, travel times, average travel speeds, travel costs, proximity to public transport.
Location-based	Indicators that measure the number of opportunities that can be reached from a fixed location using a specific mode within a specified time. They can also potentially reflect individual characteristics if the data used are differentiated accordingly (e.g. by number of jobs available to people in a certain age range or income group).	The number of jobs or other opportunities that can be reached within 30 minutes from a given place by car or public transport.
Person-based	Indicators that analyse accessibility at the detailed individual level based on time-space geography (i.e. on a micro level).	Indicators showing travel times varying according to ownership of a vehicle at different times of day; access to specific types of jobs depending on level of education.
Utility-based	Indicators that measure welfare benefits people derive from access to spatially distributed opportunities.	Logsum indicator – consumer surplus ("willingness to pay") under a range of transport planning scenarios.

Source: based on Geurs (2018).

To simplify the understanding of different types of indicators, Geurs and van Wee (2004) built a conceptual framework that categorises indicators (Table 1). Geurs (2018) argues that different perspectives tend to focus on different components of accessibility, and thus often involve indicators that concentrate on particular elements. For instance, while transport planners tend to focus on the transport component of accessibility, urban planning practice has often placed more emphasis on metrics reflecting land use factors. Practice has shown that breaking this silo-type of thinking promotes a more holistic approach and could be achieved by using a combination of indicators and conducting co-ordinated analysis by relevant authorities.

Using this framework, Geurs (2018) discusses advantages and limitations of the different categories of indicators, as summarised below.

Infrastructure-based indicators

These indicators allow evaluation of the relative quality of public transport infrastructure, rather than ultimate accessibility levels. One shortcoming is that they do not incorporate a land use component and so provide no information on the interaction of transport and land use. These indicators can potentially include the individual and temporal component by measuring access at a particular time for a particular social group.

While considered valuable for regional connectivity analysis, these indicators are generally poorly adapted to measurement of accessibility levels in dense urban environments, as indicators of this category often overlook the importance of non-motorised modes. Additionally, infrastructure-based indicators tend to disregard the equity and distributional and justice effects of accessibility and thus are less suitable for social evaluations in the form of equity-based analysis. For instance, they do not indicate whether transport improvement would actually meet various groups' access needs.

Location-based indicators

Unlike infrastructure-based indicators, location-based indicators can capture both the transport and land use components. However, land use is often included only in a broad way, disregarding competition effects. As an example, an indicator may reflect access to schools but not account for the types of schools to which different people want access, nor the competition for access to a specific school. A common version of these indicators (the simplest contour-based indicators) also makes use of thresholds (e.g. number of services reachable in 30 minutes), with all activities within and beyond the threshold treated as equally important.

More complex measures of this type, such as potential or gravity-based accessibility indicators, can address related shortcomings. These indices include an impedance function or sensitivity cost in the equation, which decreases the desirability of routes according to given characteristics – distance or road quality, for example. Simply put, destinations that are closer to the origin, or served by better roads, are given a larger weight than those that are farther or have poorer roads.

These indicators can also incorporate competition effects. Joseph and Bantock (1982) and Shen (1998) (both cited in Geurs, 2018) developed a way to add competition effects by evaluating supply and demand at different locations. They did so by dividing supply at the destination (e.g. number of doctors in a given zone) by the demand potential (e.g. the relevant population within reach of that zone). The indicator evaluates the resulting "relative supply" for all destination zones within reach of the origin. It can reflect that availability of a doctor decreases as demand by the population living near that doctor's practice increases. However, this approach does not show that demand for the doctor decreases as the number of other doctors in the neighbourhood rises. While improving result accuracy, the development of potential indicators entails more analysis and data requirements than simpler contour-based versions of these indicators. It should also be borne in mind that potential indicators result in ratio values, which are rather difficult to communicate and interpret.

Like infrastructure-based indicators, location-based indicators can be generated through the use of differentiated data for particular groups (e.g. based on age, social status, income, etc.). This method for analysing interpersonal differences is less sophisticated than the rationale behind person-based indicators founded in time-space geography (discussed below). However, the approach can provide interesting insight regarding the situation of various user types and population groups in a relatively simple manner.

Person-based indicators

Person-based indicators are more theoretically advanced accessibility indicators as they incorporate the temporal and individual components of accessibility in a very detailed way. Founded in space-time geography, these indicators recognise that activities occur at specific locations for finite periods. They express personal accessibility in terms of the potential to participate in activities through a space-time prism, which delineates the set of possible paths through space and time that an individual can follow within a given time.

In simple terms, person-based indicators allow reflection of accessibility levels by taking into account differences in needs, abilities and opportunities between individuals or groups. They make it possible to link accessibility to wider policy objectives, in particular to social inclusion goals, as the individual component in accessibility is crucial in equity and distributive justice evaluations (Geurs, 2018). However, these indicators disregard competition effects (e.g. competition in the job market) and often simplify the transport component of accessibility by, for instance, excluding from the analysis impedance factors such as transfer time, travel cost and delay due to congestion.

Utility-based indicators

Utility-based indicators are particularly suited for economic evaluations (Geurs, 2018). For instance, the logsum indicator discussed during the workshop was highlighted as a valuable tool for economic appraisal of transport investment. Logsum measures the change in consumer surplus that results from a transport infrastructure project. With logsum and other utility-based metrics, accessibility levels are measured through discrete choice modelling, i.e. the probability that an individual chooses an option among a set of alternatives.

These indicators can give a more realistic description of an individual’s behaviour. Depending on the elements included in the formula, they can account for all modes of transport. However, they are highly complex and very data-intensive, which makes them hard to interpret and communicate. Additionally, as they focus on absolute levels of welfare derived from accessibility, they do not take into account interpersonal differences in terms of benefits derived from access to specific services and opportunities. Equity and social attributes in terms of access are thus excluded from the analysis.

Choosing the right indicators

No agreement has been reached on which accessibility index might be the most suitable for assessing land use and transport systems. Where experts agree is that a wide set of indicators is necessary to support and guide policies and investment decisions (i.e. to develop an accessibility-based decision-making framework). The set can be chosen by analysing how strengths and weaknesses of different versions make them more or less suited for a given purpose.

Each indicator category discussed above can have varying degrees of complexity. Location-based indicators are more complex than infrastructure-based indicators. The most complex of all are person-based and utility-based indicators. As complexity increases, so does the effort needed for calculation and update. Interpretation of and communication about these indicators become more challenging. Adopting one indicator perspective over another involves trade-offs. In general, theoretically complex and disaggregated indicators based on sophisticated modelling approaches tend to prevail in accessibility research due to their explanatory power. However, they are used less in planning practice, as they require highly detailed information and are often case-specific.

Overall, understanding the limitations and advantages of different indicators is central to their correct application in practice. Only then can the choice of indicators be truly matched with the goal of the study and wider policy objectives to yield meaningful results. Geurs (2018) concludes that some indicator categories are more suitable for particular purposes than others:

> 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 [utility-based] indicator is probably the best suited for the job.

Transport for London (TfL) provides a valuable example of how a range of indicators with various degrees of comprehensiveness and complexity can be used for planning. The introduction of the Public Transport Accessibility Level (PTAL) – a relatively simple infrastructure-based indicator – accompanied by an online connectivity assessment toolkit has allowed TfL to set common standards, making accessibility considerations a central criterion for decisions by multiple stakeholders (e.g. local authorities, the professional planning community, developers). In addition, TfL increasingly uses complementary indicators. It applies multiple location-based measures (catchment analysis), including sophisticated tools employing information on accessibility to different points of interest (e.g. the Access to Opportunities and Services indicator), to support strategic planning as well as specific interventions. The next chapter addresses this in detail.

Accessibility indicators for planning

Accessibility indicators can be used in a variety of ways to improve planning. They can be applied descriptively to identify lack of accessibility to essential services in certain areas (i.e. to take stock of accessibility gaps). They can also be used to assess how various policy or infrastructure alternatives might change accessibility levels across territories and for different users, demonstrating how given options would contribute to or undermine the attainment of wider sustainability goals. Additionally, accessibility indicators can be used in *ex post* analysis, comparing a previous situation to the current one after implementation of a specific action.

Systematic inclusion of accessibility indicators in planning frameworks is complex. While a plethora of measures have been developed in academic settings, accessibility indicators are still highly marginalised in planning practice. A review of 23 accessibility indicators developed in Europe showed that less than 40% had been used as part of a planning process (Hull, Silva and Bertolini, 2012a). To a great extent, accessibility indicators are systematically used in planning only when researchers, planners and policy makers can easily and intuitively understand and interpret the meaning behind them. Otherwise, even comprehensive and technically sound tools will not be used in day-to-day practice and will thus have no impact on policy making.

Accessibility-based planning in the United Kingdom

The United Kingdom (UK) provides a valuable example of accessibility indicators becoming important elements for guiding decision-making. The adoption of the Social Inclusion Agenda of 2004 triggered accessibility-based planning in the UK through an explicit requirement to focus on the people's needs for access to services and opportunities via transport (Halden, 2011).

The UK Department for Transport (DfT) took a co-ordinating role and produced Guidance on Accessibility Planning in Local Transport Plans (DfT, 2007). Its purpose was to provide support to lower levels of government on accessibility planning. Under this guidance, local transport authorities are required to develop and implement an accessibility strategy. The strategy should include a vision and objectives for enhancing accessibility, and explain how the accessibility objectives link to and are aligned with wider national objectives (DfT, 2014). Since 2007, the DfT has required local authorities outside London to set a target for at least one local accessibility indicator as part of their local transport plans (Inayathusein and Cooper, 2018). The indicator reflects the proportion of the resident population that can access a service within a certain time (e.g. the percentage of 16- to 74-year-olds within 20 minutes of an employment centre). London boroughs were not obligated to report on accessibility because TfL is directly accountable for ensuring good access and because most of the DfT targets would be met within the Greater London area due to the high levels of density and connectivity of the public transport network.

When accessibility indicators have been used in making decisions regarding the location of basic service facilities, they have shown potential to bring relevant benefits. Accessibility-based assessment makes it possible to look at transport-related needs when aiming to improve access to basic services rather than exclusively considering construction of facilities and delivery of services on site. This improves clarity on the full cost of meeting well-being goals and enables better decision-making for the public budget. Such analysis may also encourage looking beyond sectoral budget allocation and shift funds towards enhancing widespread access to particular services, thus improving the transport network.

Box 1. Using accessibility indicators to plan health facility locations in Liverpool

A redevelopment plan for the Royal Liverpool Hospital included relocating the city centre site to a peripheral location. Merseytravel, the local transport authority responsible for co-ordinating public transport in the Liverpool City Region, used accessibility analysis to estimate the impact of the more distant location, and to identify where new bus services would be needed. The assessment showed that providing the bus services required to maintain accessibility levels similar to those before relocation would mean a costly investment. When faced with the potential transport cost of the relocation, the health authority decided it would be cheaper to redevelop the hospital on the city centre site.

Source: Halden (2014).

A good illustration of the above is that of health services. Without conducting accessibility-based analysis, health authorities will often choose to build a new hospital on cheaper land far from a city centre so to make better use of the health budget. However, the new, more distant site now requires additional public transport so to mitigate congestion on the road network and avoid social exclusion among those who cannot reach the hospital with the existing infrastructure. When local transport authorities account for this expense, the full cost of the option often turns out to be high. Although such cases remain the exception, transport authorities have used local accessibility plans to help the national health authorities (NHS) make site decisions, as in the Royal Liverpool Hospital case (Box 1).

The evolution of Transport for London’s accessibility indicators

London’s accessibility-based planning framework is a well-established example of relatively simple yet robust accessibility indicators being systematically integrated into planning procedures. Transport for London (TfL) has developed accessibility-based analysis techniques and indicators that are used in planning both the transport network and commercial and residential development (Inayathusein and Cooper, 2018).

Public Transport Accessibility Level

The Public Transport Accessibility Level (PTAL) index is a central component of London’s planning framework. PTAL measures accessibility to the public transport network across Greater London. The score provides information on how close a selected point in the city is to frequent public transport services. The methodology takes into account walking access time, service reliability and average waiting time (Box 2).

With systematic use of PTAL and complementary tools, TfL has been able to develop a planning framework that supports the objectives for sustainable urban growth identified in the London Plan, a strategic planning document setting out an economic, environmental, transport and social framework for the development of the capital. PTAL is used for several types of analysis, including strategic planning, assessment of whether a change in transport services is acceptable, and identification of locations where public transport accessibility is low and potential intervention is needed. The main strength of the PTAL approach is that it is easy to understand. Unlike more sophisticated modelling approaches, PTAL allows for direct data visualisation using a contour map, where patterns of public transport provision are clearly shown (Figure 2).

Box 2. Calculation methodology for the Public Transport Accessibility Level

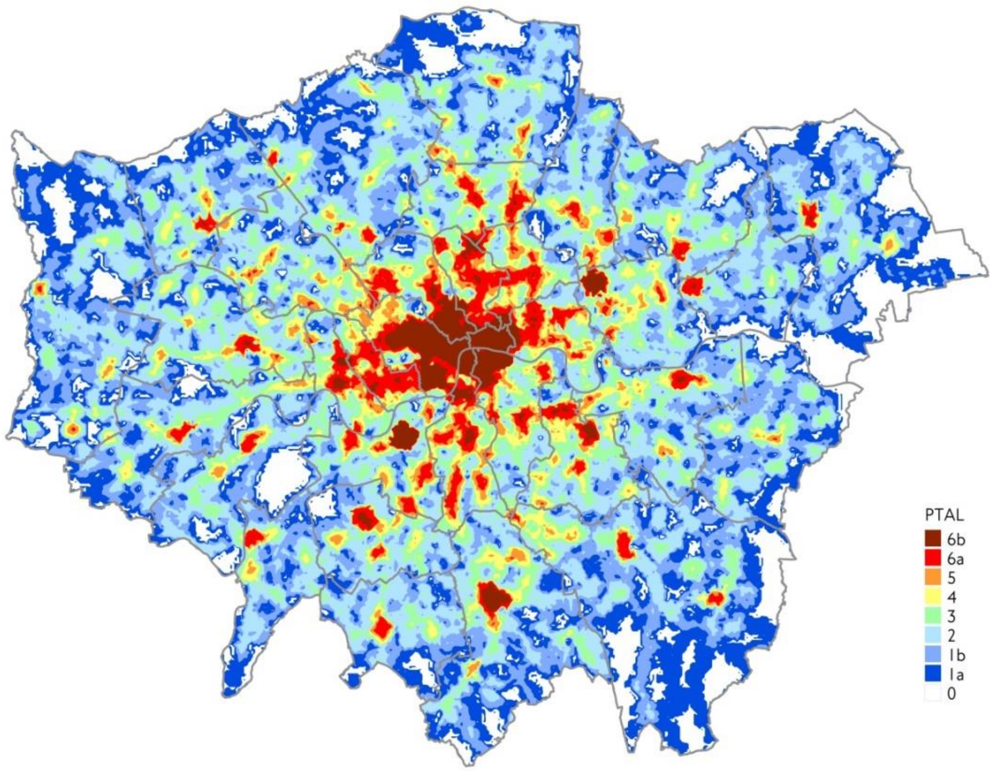
The Public Transport Accessibility Level (PTAL) deals only with either the origin or the destination of a journey, using a set of formulae to measure the intensity of public transport provision at a particular point (e.g. bus stop, train station) within easy walking distance of an area or site (Hull, Silva and Bertolini, 2012b). The formulae take into account the walking time from specified points of interest to all public transport service access points (SAPs), i.e. bus stops, rail stations, light rail stations, underground stations and Tramlink stops, within a defined distance threshold. This is combined with the average time a user must wait for the next service. The methodology incorporates several steps for calculating the final indicator:

- The first step is to calculate the walking access times from a point of interest to the SAPs within a defined catchment. Several parameters define the walk catchment area. For bus stations, maximum walk time is 8 minutes (or 640 meters). For other modes, maximum walking time is 12 minutes (or 960 metres). Any SAP beyond these limits is rejected.
- Valid routes to each SAP are then identified, and average waiting times are calculated by adding the levels of service frequency to the walking times for all routes available from a given location.
- The next step is to add a reliability factor and calculate the total access time, which is the sum of walking time and average waiting time, adjusted by the reliability factor.
- Total access time is then converted to equivalent doorstep frequency (EDF), a measurement comparing the benefits offered by routes at different distances. The EDF measures what the service frequency would be if the service were available without having to walk. This allows a comparison of routes according to service frequency: routes with the highest service frequency score are assigned a weight of 1, while all others have a weight of 0.5 (TfL, 2015).
- The final indicator is based on a sum of the EDFs of all routes within the acceptable walking distance, but weighted as described above. A separate accessibility indicator (AI) is initially calculated using this methodology for various modes, including bus, rail, underground and tram. A total AI is then calculated for the selected location as the sum of the AIs for all modes. This AI is converted to PTAL using a scale from 0 to 6 (TfL, 2010).

Thus, each location is given a score from 0 to 6, with 0 representing the lowest level of access and 6 the highest. The measure reflects walking time from the point of interest to public transport access points, the reliability of the service modes available, the number of services available within the catchment area and the level of service at the access points, i.e. average waiting time. It does not consider the speed or utility of accessible services; crowding, including the ability to board services; or ease of interchange. The main data sets required for producing PTAL indices are those of the public transport network, including locations of public transport stops, delineation of routes and schedule frequency (Wu and Hine, 2003).

Source: based on Inayathusein and Cooper (2018), TfL (2010).

Figure 2. Map of public transport access levels in Greater London



Source: Inayathusein and Cooper (2018).

Another development that contributed to the systematic use of PTAL was the Web-based Connectivity Assessment Toolkit (WebCAT). This open web portal for connectivity assessment makes a suite of TfL tools, data and analysis easily available to boroughs, developers and planners. An intuitive and simple interactive mapping tool, WebCAT allows users to easily identify PTAL values for any location in London, create their own PTAL maps and view PTALs for future development scenarios. Its data requirements are relatively easy to meet, facilitating regular maintenance and data updates.

PTAL is an essential tool in the London Plan for setting out indications for appropriate density for new developments across Greater London. In particular, PTAL was the basis for the development of the Sustainable Residential Quality Matrix, adopted in 2016. Embedded in the London Plan and based on PTAL values and location type (central, urban or suburban), the Matrix provides clear guidance on appropriate ranges of density for future development. The ranges are based on the principle that areas with better public transport access may be developed with higher density of housing and offices.

The London Plan also uses PTAL for recommending parking capacity of housing and commercial developments. The Plan defines maximum parking standards for new development on the principle that locations with high public transport accessibility (i.e. higher PTAL areas) need fewer parking spaces (London Plan, 2018). PTALs are further applied in monitoring the share of business and commercial activities in areas with good connections to the public transport network (i.e. with a PTAL of 5 or above).

This aides in verifying compliance with the London Plan goal of having a high share of workplaces well connected to public transport (Inayathusein and Cooper, 2018).

PTAL was also used in identifying key areas in which to encourage new development within London, thus promoting location efficiency, called Opportunity Areas (OAs) and Intensification Areas (IAs). OAs are brownfield sites with space for large numbers of jobs and homes (typically 5 000 and 2 500, respectively) and existing or potential access to public transport. IAs are built-up areas with significant capacity for densification. They have good existing or potential public transport accessibility, which can support higher densities. Areas designated as OAs or IAs receive support from the Greater London Authority for development of an Opportunity Area Planning Framework and spatial strategies, including strategies for infrastructure provision, accessibility improvement and enhancements to the public realm (London Plan, 2018).

PTAL is also playing a role in the DfT's development of the Transport Assessment framework in the Greater London area. The framework requires developers to submit a document called the Transport Assessment for any new development likely to have significant transport implications. The Assessment is used to determine if the development's impact on transport conditions would be acceptable. Developers lean on PTAL as the indicator in such assessments for London projects, as it helps them evaluate how new development would affect accessibility to public transport in a selected area and determine the acceptability of the impact. PTAL also helps in negotiations with private developers, providing the evidence base for their contribution to the cost of the transport infrastructure required by a new development (ITF, 2017).

The PTAL method is essentially a way to measure the quality and density of the public transport network at any location within Greater London. While it provides a useful indicator of local accessibility and allows easy comparison of areas across the city, one criticism is that it assumes access to a public transport network includes access to reasonably well-integrated rail and bus services and, by implication, to a range of final destinations. But PTAL does not in fact measure access to final destinations. That said, the Access to Opportunities and Services (ATOS) indicator – a complementary TfL measure that does reflect access to destinations and is described below – shows that in the case of London, a city with a comprehensive and relatively dense public transport network, PTAL is a good proxy for access to services and opportunities. In areas of lower density, however, the PTAL method may not be applicable as they usually have a sparser public transport network with poor connections and interchange facilities.

Other criticisms are that the method does not consider travel time aspects, such as service speed, congestion, crowding, stopping vs. express services and ease of interchange. Nor does it account for availability of cycling lanes or quality of walking environment. To address some of these shortcomings, PTALs are complemented with other accessibility-based analysis techniques, described in the following section.

Complementary accessibility-based analysis used by TfL

TfL is able to demonstrate transport characteristics transparently and support evidence-based policy decisions thanks to a suite of accessibility indicators that adapt to different types of analysis. These tools are used to inform planning decisions within TfL, not to set standards for developers, like PTAL.

Among these measures are travel time maps, which reflect the time required to travel by the likely public transport routes between areas across London. The maps can show average times to a location from all other locations, average times from a location to all other parts of London, or an average of both. While PTALs are calculated for the aggregate of available public transport modes, the Time Mapping Index

(TIM) is available for individual modes (e.g. step-free public transport, buses only), and thus provides information on accessibility for various types of users. A tool for calculating the TIM and developing related heat maps is also available as part of WebCAT (Inayathusein and Cooper, 2018).

Travel time mapping provides another simple yet powerful assessment of connectivity. While PTALs capture the impact of transport improvements on local accessibility to public transport, travel time maps evaluate their metropolitan-wide impact by showing how particular improvements will affect journey times to all areas across London.

TfL also uses catchment analysis, a method based on travel time maps. Catchment analysis estimates travel time intervals and calculates the area presenting an appropriate sum of professional opportunities and other services that people can reach within an appropriate time, which TfL usually considers to be 45 minutes. Catchment areas can be plotted by taking as reference the time *to* a location and *from* a location. It contains all locations reachable within a specified travel time from a specific area or place. The logic is that most customers of a place providing a service (e.g. a shop, school or hospital) will come from its catchment area. As with travel time mapping, analysis can be conducted for different public transport modes. TfL uses the catchment area as an indicator of connectivity, since better transport makes a catchment area larger (TfL, 2010). Such analysis can show how many more jobs can be reached by looking at how a plotted area changes if a new transport route is introduced. For instance, construction of the Elizabeth Line from Abbey Wood enlarges the catchment area and thus increases the number of reachable jobs.

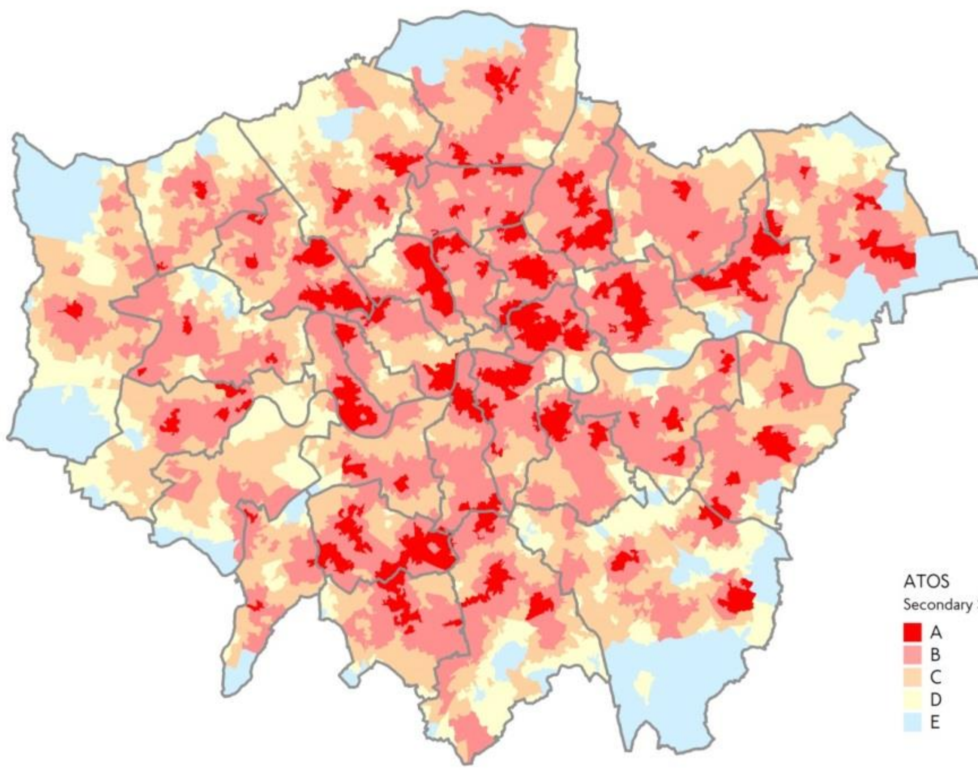
To provide a more strategic view of changes in connectivity across London, TfL uses *London-wide catchment analysis*, which aggregates time plots for individual locations and maps them for the whole London area. Rather than calculating travel times to specific locations, this method quantifies the number of services that can be reached within a given period (Inayathusein and Cooper, 2018). Such maps, for instance, those quantifying the number of workplaces reachable within 45 minutes by public transport for each zone in London, are used as a strategic indicator of connectivity in the Mayor's Transport Strategy.

Like all TfL accessibility indicators described in this section, catchment analysis can be conducted for both current and future scenarios and can thus help in evaluating the potential impact of alternative policies and infrastructure projects. Projects potentially affecting the whole Greater London area, such as Crossrail 2 – the new rail link that will connect Central London to Reading and Heathrow in the west and Shenfield and Abbey Wood in the east –, are assessed using London-wide catchment analysis to determine how many more services will be reachable within 45 minutes from each zone once service begins (Inayathusein and Cooper, 2018).

The Access to Opportunities and Services (ATOS) indicator is yet another tool TfL uses for more comprehensive accessibility analysis. Like catchment analysis, the indicator measures accessibility in terms of travel time to jobs, education, health services, retail and open spaces. Unlike catchment analysis, which shows access to the nearest destinations, ATOS reflects the degree of choice by measuring, for example, access to the nearest three schools or doctors' surgeries. A "basket" of key services is used to calculate the indicator. The services included are those identified as the most important and essential for residents' day-to-day well-being (e.g. the nearest 10 000 low-qualified and high-qualified jobs, or the nearest three primary schools, secondary schools and further education institutions). This approach reveals users' ease getting to essential services while considering a degree of choice in the services to which they are likely to go (Inayathusein and Cooper, 2018).

Depending on travel time, which includes walking (from origin and to destination) and public transport, each type of service gets an ATOS score ranging from A to E. The score at any location is based on how travel times to nearest relevant destinations (e.g. three primary schools) compare to the average travel time across all locations. For instance, the highest score, A, means travel times to relevant destinations are more than one standard deviation below the average score, while E means travel times are more than two standard deviations above the average. ATOS is a useful complementary measure that, combined with PTAL, gives a fuller picture of connectivity across London and identifies places that require connectivity improvements. It is particularly helpful when making decisions about the best places to introduce new services, such as health or education, with an aim to locate them in places with good connectivity. Figure 3 shows an example.

Figure 3. Access to the three nearest secondary schools by public transport or walking in Greater London



Source: Inayathusein and Cooper (2018).

TfL is working towards extending accessibility analysis by including cycling access to public transport through a new indicator called CYTAL (Box 3). It is also developing tools addressing walking connectivity. These developments are driven by the adoption of the Healthy Streets Approach initiated by Sadiq Khan, mayor of London, a system of policies and strategies to help Londoners move from car use to walking, cycling and public transport. Overall, TfL has made considerable progress in developing tools for assessing access through walking and cycling. However, a lack of adequate data has made it difficult to include these modes in accessibility analysis. That is also why existing indicators are limited in their application for evaluating, for instance, pedestrian links. In particular, the limited availability of comprehensive data on the quality and usage of pavements and cycling lanes, and the quality and affordability of cycle parking, impedes detailed analysis of neighbourhood-level accessibility. Additionally, the increasing uptake of app-based mobility services brings new demand for understanding how these services are used and how they can enhance access, in particular for rural and peripheral areas.

Box 3. London's Cycle Access Level

The Cycle Access Level (CYTAL) extends the catchment area of the Public Transport Access Level (PTAL) by including cycling in addition to walking as an access mode for public transport. To develop this metric, the Cycling Network Model for London, or Cynemon, was generated to closely estimate the routes taken by cyclists. Cynemon estimates cycling routes, journey times and flows at a strategic level across London. It shows all cycling trips between eight o'clock and nine o'clock on an average weekday morning in the autumn of 2014. To calculate CYTAL, a 100-metre grid is overlaid on the Cynemon network. For each grid sector, CYTAL calculates the number of rail and underground stations within five minutes' cycling. It does not calculate cycling access to bus stations, as it is assumed that bus services are accessed by walking only.

CYTAL has the same value scale as PTAL, allowing the two metrics to be compared. The main purpose of comparing CYTAL and PTAL is to highlight areas where PTAL is low by itself but can potentially be raised by including cycling as an access mode. This measure, however, does not take into account the availability of cycling infrastructure, such as parking at origin or destination, or the suitability of the cycle network for a given trip. Thus, this indicator serves TfL for strategic cycling analysis and helps identify areas for potential future cycling infrastructure investment in the Greater London Area.

The methodology is still under development and several issues need to be resolved or refined, such as questions related to the most appropriate maximum distance for station access; differences between inner and outer London; and access to bus services. Most importantly, such analysis requires additional quality data on availability of cycling infrastructure, including parking and dedicated cycling lanes, and on perceived safety and overall convenience of cycling in various areas across London.

Source: based on TfL (2017).

Beyond supply-based indicators

Supply-based indicators using transport network data and the locations of jobs and services, such as those described above, are valuable tools for accessibility analysis. However, they do not capture the actual accessibility needs of various groups of people. This is an important factor to consider. Different user categories, differentiated by age, occupation or gender, for example, may require different levels of access through the different modes. Combining supply-based indicators with data reflecting these aspects can enrich analysis and produce a more comprehensive picture. First, however, particular surveys must be conducted to collect information that allows such analysis.

In the UK, the DfT considers subjective measures of connectivity by analysing data from the British Social Attitudes survey in addition to supply-based accessibility indicators. The survey's questions on the extent to which people can travel without a car improved understanding of the user's perspective of public transport accessibility gaps. The DfT also refers to the UK's National Travel Survey, which asks questions about travel experience, in identifying where poor connectivity is a problem and in identifying areas where transport improvements must be prioritised (Cooper and Penrose, 2018).

Di Ciommo (2018) developed an indicator measuring "inaccessibility" of needed activities. She built a methodology identifying people's needs using travel survey data, including data on mobility patterns and people's satisfaction with their trips in terms of travel time (Box 4). A lower value indicates that people's need for a certain activity (e.g. access to employment, school or hospital) is not met due to long travel times related to poor transport provision.

The indicator clearly showed correspondence between revealed needs and inadequate public transport. By eliciting users' unmet needs, the indicator also served to identify the transport user groups (that are particularly vulnerable due to limited accessibility to activities. With 62% of retirees assessing their satisfaction negatively, analysis showed that retirees' need to reach health facilities by public transport is largely unmet; while 53% of housewives feel their need to do daily shopping is unsatisfied. The indicator illustrated, then, that strategies and funding should be oriented towards increasing access to shops and health centres for these two groups instead of solely promoting access to jobs as a generalised and unique access goal for all population groups.

The indicator was also used to assess certain transport planning strategies aimed at poverty corridors in Barcelona. This assessment identified a lack of provision in the public transport network to certain areas of the city, causing transport-related vulnerability among specific groups. It confirmed the need for a bus rapid transit corridor in the eastern part of the Barcelona metropolitan area.

Box 4. Methodology for the In-accessibility Index

The In-accessibility Index was developed for four municipalities of the eastern Barcelona Metropolitan Area, but could be calculated for an entire metropolitan area. The four municipalities were chosen because of their proximity to each other but also their differences in terms of a) income and population profile and b) quality of public and private transport provision.

The indicator is based on information from travel surveys on people's satisfaction regarding their commuting experience. Commuters living in a given area (eastern municipalities) were first grouped by trip typology (people with the same trip purpose, transport mode and length of trip were included in the same group). Second, based on users' level of satisfaction, appropriate time thresholds for each trip typology were identified. To identify the thresholds, Likert's 10-point scale (the same scale used to evaluate the Spanish school system) was applied to categorise users according to their satisfaction based on the time threshold for the typology of each trip they needed to make. In this methodology, satisfaction of needs refers to an individual's satisfaction with the travel time to the destination where needed activities take place. The indicator is then calculated using this information and translated into a scale of 0 to 1, with a value of 0 showing a completely unmet need (resulting from very low satisfaction with the travel time) and 1 indicating that the user is completely satisfied with the travel time. The last step of the analysis was identifying the population groups that seemed to experience the least satisfaction when it comes to meeting their needs.

Source: Di Ciommo, F. (2018).

Accounting for behaviour and infrastructure quality

Improving walking and cycling accessibility indicators is a first-order priority for improving overall accessibility analysis, particularly at the neighbourhood level. Transit-first policies, walkable-street initiatives and Vision Zero goals, endorsed by an increasing number of cities, fundamentally rely on pedestrian infrastructure. This is not just pavements, but safe, comfortable, interesting and – most importantly – interconnected pavements. Thus, there is a need to move beyond measuring availability of infrastructure to examine how people actually behave and how infrastructure (particularly for pedestrians) is being used.

Several challenges currently need to be addressed. First, pedestrian accessibility is often mapped using road centre-line data. This leads to: a) inaccuracies (e.g. streets with no sidewalks), b) simplifications (e.g. assumptions that buildings can be directly accessed on both sides of a street centre line when, in reality, crossing a street is only allowed at certain locations), and c) misrepresentation (e.g. assuming pedestrian connections on vehicular routes where there are none). Additionally, transport accessibility measures are calculated using origin/destination travel data, which are less available for local pedestrian travel. This also leads to rather simplified and often misleading analysis of pedestrian accessibility.

Second, when considering pedestrian accessibility it is important to look beyond access to jobs and focus on access to amenities as well. Evidence suggests that work trips constitute a decreasing proportion of total travel (22% in the United States, 20% in Sweden), and most people do not live close enough to their workplace to be able to reach it by walking or cycling (Grengs, 2015). Many other spheres of everyday life, such as grocery shopping, leisure activities, healthcare and restaurants, are more prone to changes in access by active travel, i.e. walking and cycling (Páez, Scott and Morency, 2012). Some studies have shed light on the extent to which various social groups have access to well-specified facilities, or what facilities certain segments of the population need and want in close proximity. According to the exhaustive overview of Lee and Moudon (2008) grocery stores stand out as the most visited neighbourhood destination. Likewise, Páez, Scott and Morency (2012) found that shopping and health facilities were the most important destinations to have within short distances.

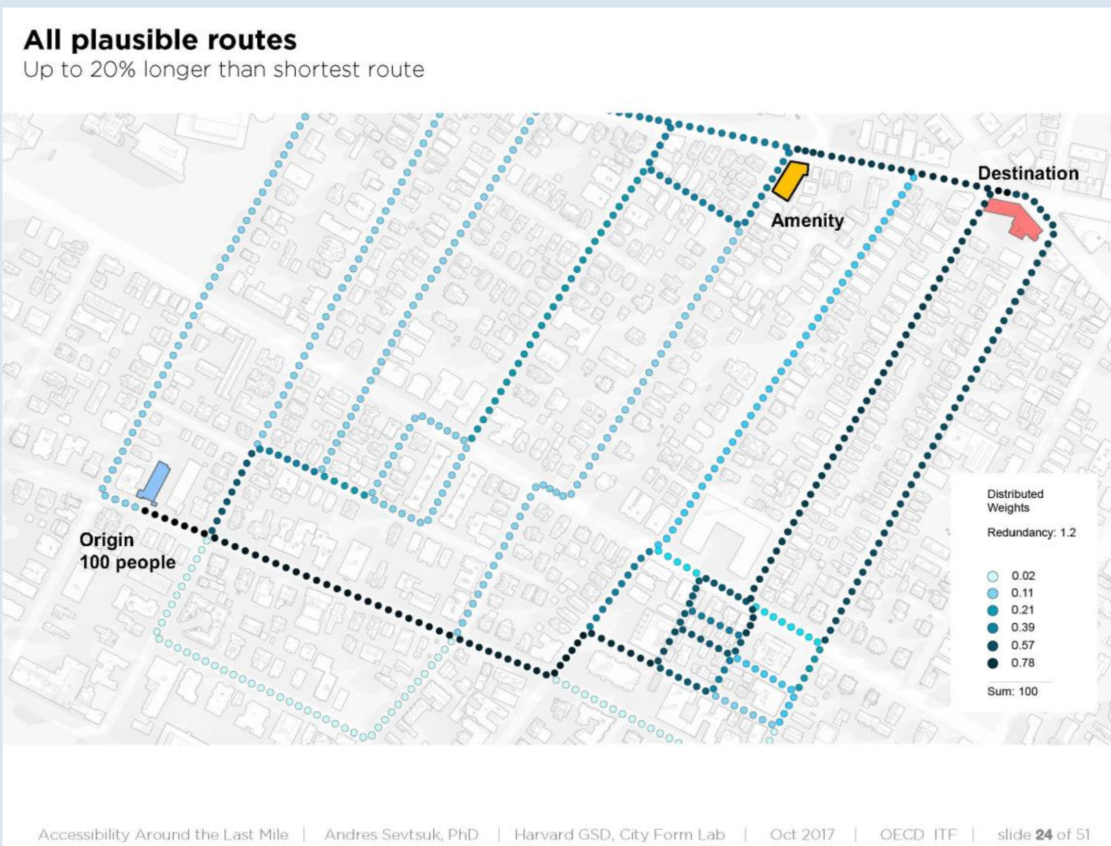
Another major shortcoming of current accessibility studies is that how and where people walk around a city is often ignored. Accessibility research often overlooks to what extent amenities can become more accessible if located on the routes people are most likely to take, such as on the way to a public transport stop. To address this, Andres Sevtsuk from the City Form Lab at the Harvard University Graduate School of Design proposed a tool that has the capacity to capture how people walk around a city. To measure accessibility, it takes the routes most often used by residents – like the route to a public transit station, for instance – and treats the entirety of those routes as origins, instead of using fixed locations, like homes or workplaces. This approach thus reveals how people behave and use pedestrian infrastructure.

Such techniques can significantly change the understanding of how, for instance, to plan commercial activities. It may be found that placing amenities near places that are on highly-used walking pathways to public transport, rather than nearer to people's homes, could attract more customers and provide more convenient access to goods. Indices based on behaviour and infrastructure can be used to predict land values, to locate amenities or to evaluate infrastructure investment benefits at the local scale. Box 5 looks at the application of the City Form Lab technique, for example, in Singapore and Surabaya (Indonesia).

Box 5. Pedestrian accessibility "en route"

The City Form Lab worked with Singapore's Housing Authority to develop a new planning standard for commercial developments in the town of Punggol and identify the most efficient locations for such developments. In addition, the Lab identified the most probable routes to public transport stations. First, all potential routes to public transport stations were mapped. Segments of routes that overlapped were assigned an overall higher probability. Second, a betweenness centrality index, which redistributes weights from origins to destinations, was applied for the most probable routes. Simply put, initially an origin is given a weight of 100. The betweenness centrality index redistributes this weight equally across all points on the route from origin to destination.

Figure 4. Route probability modelling



Source: Sevtsuk (2017).

The index allowed the lab to test how the number of estimated store visits was affected by assumptions on whether shoppers came from home or visited shops en route to local public transport stations. The result of the analysis indicated that positioning stores on commuting paths to transit stations rather than in proximity to housing could lead to a projected 10% increase in store visits. The Singaporean experience can be extended to other contexts for planning retail developments and other public facilities to maximise both user access to and use of the developments (e.g. number of visits to retail centres).

In 2015, the City Form Lab and the Hansen Partnership participated in Surubaya's Urban Corridor Development Programme in Indonesia. In this initiative, application of the betweenness centrality index made it possible to identify and prioritise enhancements that would avoid deterioration from rainfall on the street segments that would be most critical for access to future light rail stations. The assessment recommended prioritising investment on 17 km of paths within the areas around essential metro stations. The investment proposal took into account improvements that would reduce access barriers for the people who mostly used the amenities, particularly vulnerable groups such as women and children.

Source: based on Sevtsuk (2017).

To be useful, tools for analysing pedestrian accessibility also need to measure the quality of the pedestrian environment. Using data on the quality of pedestrian accessibility and contrasting it with potential gravity-based indicators may show that, in some cases, investing in improved quality of existing infrastructure or the surrounding urban environment is more important than increasing its quantity. For instance, a study by the Catholic University of Chile underlines the importance of analysing walking accessibility to public transport by measuring both the quantity of public transport stops reachable within a reasonable walking time and the quality of the urban environment (ITF, 2017). The findings emphasise the way the accessibility gap between higher and lower income areas increases when factoring in user perceptions regarding the public transport service level as well as the quality of the walking environment.

Although useful for improving planning and assessment, indicators that take non-motorised modes into account, such as those described above, have not been widely developed or used for planning. One barrier is the persistent focus of data collection efforts and analytical tools on examining data on traffic – primarily, and in many cases exclusively, on road networks. Analogous data on pedestrian infrastructure – pavements, ramps, stairs, overpasses, underpasses, covered walkways – remain largely missing for most cities. Pedestrian mapping, modelling and predictions are thus grossly under-represented and often missing in urban transport investment discussions. Transport debates are often skewed towards topics rich in data: vehicle throughput, for instance, which is monitored on individual streets in many cities, is a key parameter for new street design and investment. Not only are comparable data describing pedestrian throughput on streets often unknown, but the locations and types of pavements are rarely mapped or updated. Hence collection of pedestrian data is an important step in developing more detailed walking accessibility indicators for designing policies to meet key priorities for more sustainable urban development. It is essential to establish best practices for pedestrian data collection, management and analysis that can serve to identify which types of data to collect, as well as the methods and counting technologies required.

Accessibility indicators and transport project appraisal

Increased interest in the effect of transport investment on the local economy has been accompanied by criticism of appraisal tools used for scheme prioritisation. In particular, there is growing concern for the focus on cost-benefit analysis (CBA), as it fails to capture many relevant benefits. Conventional appraisal usually ignores how modified accessibility affects social outcomes, including participation in the workforce, social inclusion and community cohesion (Lucas, van Wee and Maat, 2016). Critics worry that projects that make significant improvements to non-motorised trips compare poorly with those that cut travel time on motorised transport. This is due to the conventional approach to CBA that relies on travel time savings as a proxy for most of the benefits associated with transport investment. This traditional focus on travel time savings often leads to prioritisation of schemes that are misaligned with increased sustainable mobility goals. All else being equal, cars are indeed faster than public transport, serving a larger area in the same amount of time. As such, improving a link in a fast network like a road is likely to generate more travel time savings than a comparable improvement in a slower public transport network.

Another issue is that lower-income individuals, who are often frequent public transport users, tend to have a lower value of time and are less likely to travel by car. Any potential disadvantage to this user group tends to be overshadowed by the benefits to car users (Martens and Di Ciommo, 2017).

Some countries mitigate these effects by using “equity values” of travel time savings. For instance, the value of time used in the appraisal practice in the United Kingdom (UK) is based on the average income of travellers nationally and the type of journey (work- or non-work-related). When used in the CBA, these equity values of the value of travel time savings prevent a concentration of investment in high income areas, and are thus regarded as fair. Still, in many cases, user-benefits analysed through the quantitative steps of CBA do not account for the social value that people derive from improved access (i.e. emotional well-being associated with better access) nor do they adequately capture the impact of location changes.

More fundamentally, CBA is designed to rank similar projects, i.e. to assist in setting priorities between similar road investments that competing for funds. It should not be used to compare dissimilar projects, e.g. investment in a new road rather than in public transport or a protected cycleway network. But inevitably, benefit-cost ratios do tend to influence decisions on the allocation of funds across sectors and between dissimilar projects.

Transport project appraisal in the United Kingdom

The Transport Investment Strategy published in 2017by the UK’s Department for Transport (DfT), specifies improvement of accessibility (referred to as “connectivity”) as a central objective of transport policy. This strategy puts an emphasis on improving connections: between people and employment, people and services, and business and economies (Cooper and Penrose, 2018). Scheme promoters are expected to develop five cases: financial, commercial, management and – most importantly, strategic and economic.

The strategic case sets out the objectives of the scheme and establishes how these objectives are going to be achieved. It is important that scheme promoters set out how these objectives fit into wider national strategies. Once the strategic case is developed, the economic case assigns value to the impacts of the scheme and determines the degree to which the scheme meets the objectives. In practical terms, the strategic case would, for instance, set the objective of increasing accessibility to productive jobs, while the economic case would focus on measuring if and to what extent the scheme has this impact. The cost-benefit analysis is conducted as part of the economic case.

The past 15 years have shown an increasing interest in quantifying the potential ”wider economic benefits” that go beyond travel times savings that transport investment can bring. In the context of the UK’s transport appraisal this focuses particularly on the agglomerations of economic activity. Much of the agglomeration benefit arises from effectively bringing larger numbers of people and businesses closer together. In high-value service sectors like finance, this includes creating an environment where excellent accessibility for short trips is the essential feature, opening opportunities for frequent face-to-face contact and serendipitous meetings.

Appraisal practice is evolving. It is adding these location benefits to monetised time savings and vehicle operating costs and including changes in land-use and the location of activities as well as agglomeration effects (Cooper and Penrose, 2018). The modelling techniques developed to make these estimates focus on the mass and concentration of people that can be delivered to centres of economic activity by the transport system.

Transport appraisal is carried out under an overall Value for Money (VfM) framework developed by the DfT. This, in turn, was developed in accordance to the Treasury’s appraisal guidance with the aim of having a consistent decision-making framework involving the use of public funds across government. Within this framework, each project proposal is assessed according to different impacts: monetised, evolving monetised, indicative monetised, and non-monetised. Each of these impacts is treated differently in the VfM assessment, and informs the value for money category at different stages (Box 6). Some of the elements related to accessibility are monetised (e.g. agglomeration effects), while others are presented in different forms (mapping, qualitative assessment) and used to inform the investment decisions. Although reported separately, these additional indicative elements, such as movement to more productive jobs due to improvements in the transport network and other non-monetised impacts (i.e. improved security, landscape, the transport system for people with physical and hidden disabilities), can guide investment decisions by influencing VfM category. The assessment results are presented to decision-makers in the form of an Appraisal Summary Table that highlights the non-monetised benefits and costs alongside the monetary assessment results and indicates compatibility or incompatibility with key government policy objectives.

The DfT developed Web-based Transport Analysis Guidance (WebTAG) to support transport appraisal. WebTAG is a resource that is used across the spectrum of transport analysis and provides guidance to scheme promoters on transport modelling and appraisal. It covers national transport projects, major local schemes and rail projects, among others. WebTAG provides a consistent approach to measuring scheme costs and benefits. It also helps local authorities in meeting local transport needs more effectively through improved access to jobs and services, particularly for vulnerable population groups. It is used to inform value for money considerations by showing the impacts of transport schemes on the economy, environment and society, as well as highlighting distributional effects. Different teams within DfT are responsible for monetised and non-monetised impacts and verify that scheme promoters follow WebTAG guidelines (DfT, 2013).

Box 6. Stages of Value for Money assessment in WebTAG

Each type of impact is included in the value for money assessment sequentially.

The first stage includes generation of an initial value for money metric upon which other, less certain metrics are based. *Established monetised impacts* are the main inputs in the Benefit-Cost Ratio (BCR), as the methodologies for assessing these impacts are the most advanced. These impacts include journey time savings, vehicle operating costs, journey costs, impacts on accidents, journey quality, greenhouse gases and indirect taxes.

The *evolving monetised impacts* are subsequently added to the original assessment to generate an adjusted value of the BCR. DfT regards methodologies underpinning the assessment of these impacts as less robust, thus these impacts are used only to inform the ”adjusted BCR” metric. The elements in this category include journey time reliability, labour supply (number of people that can now access the labour market due reduced commuting costs) and static clustering (i.e. how reductions of generalised transport costs bring firms and households closer together, leading to productivity gains).

The final stage of the value for money assessment requires consideration of *indicative monetised impacts* and *non-monetised impacts*. This involves determining whether these impacts, either individually or collectively, are likely to alter the overall value for money of the proposal. Methodologies in this category are not considered robust enough for inclusion in the BCR, but are used to inform the Value for Money (VfM) category. The VfM catagory includes impacts on movement to more or less productive jobs, dynamic clustering, and landscape and dependent development. This stage of the assessment introduces variable land use and estimates the impact of relocation of employment, firms and households, typically with land use models.

Assessment of *non-monetised Impacts* is based on qualitative evaluations for which methodologies are the least advanced. These impacts involve greater judgement and do not enter the BCR calculation. This assessment section includes impacts on security, severance, townscape, accessibility (in the meaning of usability of the transport system for people with physical and hidden disabilities), affordability, etc. It is important to note that non-monetised impacts require the most work and research for improving methodologies in order to better link these impacts to decision-making. This is important for not only essentially influencing whether the investment goes to particular scheme but also to serve as a basis for the adjustment of the scheme design. DfT works continuously on improving methodologies and indicators for calculating accessibility impacts.

Source: based on Canton and Penrose (2018), DfT (2013).

A key issue with assessing accessibility impacts is the difficulty to quantify and monetise some of them. While improving methodologies for monetising accessibility benefits may help with this in some cases, in others, monetary valuation of accessibility gains - for instance when analysing distributional and spatial impacts – may be unnecessary, as a sole outcome ratio (such as the BCR) could be hiding relevant effects. Developing other methodologies that better represent the distributional and spatial impacts of transport schemes may be one way of addressing this shortcoming.

The example of the UK is particularly valuable. DfT’s value for money assessments for transport not only focus on the BCR but also present the distributional impacts (DIs) of the proposal. However, the DI analysis does not inform the final VfM assessment – it is purely for the decision-maker’s information. In practical terms, the DfT recommends that scheme promoters map the impact area of their scheme and identify the different social groups in those areas (children, people with disabilities, the elderly) and compare the impacts on those different groups. This analysis, however, is rather limited, as it does not assess the benefits that a proposed transport scheme would bring for the entire mobile population. The appraisal provides a seven-point scale from “large beneficial” to “large adverse”. It is especially important to highlight if the proposal is expected to disproportionately benefit or disadvantage particular social groups across the range of areas that are assessed. Scheme promoters also need to undertake accessibility mapping and provide contour maps showing accessibility levels for the “without scheme” and “with scheme” scenarios. The “with scheme” scenarios should reflect changes to the public transport network resulting from the intervention. (DfT, 2015)

Benchmarking accessibility

The ITF has developed an accessibility benchmarking tool for European cities as part of the joint project with the European Commission and the OECD on "Access and Safety in European Cities". The benchmarking tool and methodology are presented in detail in a report entitled "Benchmarking Accessibility in Cities: Measuring the Impact of Proximity and Transport Performance" (ITF, forthcoming), which also includes benchmarking results and their analysis for the cities covered in this study. This section presents a more general discussion of accessibility-based benchmarking tools and the elements that can make them useful to policy makers.

Benchmarking refers to creating common measures that make it possible to compare various levels of a given aspect across different dimensions. Using accessibility-based benchmarking tools for transport planning can help place accessibility at the centre of what defines good performance of mobility policy. It can also help identify land use decisions that can complement improving access. Comparing access levels is important for supporting the shift in paradigm for mobility policy that is necessary for achieving well-being and sustainability objectives. In addition, accessibility-based benchmarking tools are relevant for tracking international commitments on wider sustainability and well-being objectives, such as those in the Paris Agreement, the New Urban Agenda agreed at Habitat III, and the United Nations Sustainable Development Goals (SDGs) (Box 7).

Principles of an accessibility-based approach were set out above. The section on "Principles for effective accessibility-based decision-making" outlined ways to turn accessibility indicators into valuable tools for achieving wider social, economic and environmental objectives, namely by a) reflecting access to opportunities through looking at the interactions between transport and land use; b) considering all relevant scales for the analysis of accessibility, specifically the neighbourhood scale; and c) including all modes in the indicator. Following these principles is also central to ensuring that benchmarking tools support well-being and sustainability goals.

For benchmarking purposes accessibility indicators can also be combined with other indicators to better track impact. For instance, the ITF's proposed benchmark makes it possible to combine information on the levels of access to services by different transport modes with data on income distribution of an urban population. This type of analysis sheds light on the link between income inequality and access to opportunities in urban areas. Similarly, this approach has potential for analysing links between transport accessibility and greenhouse gas emissions from the transport sector. This would increase understanding of how differences in proximity of activities and in relative performance of different modes of transport shown by different cities are playing out in terms of emissions.

Benchmarking accessibility can also support the creation of common accessibility-oriented policy frameworks. Common metrics used by all relevant actors in their individual accessibility-related actions can help actors at different international, national, regional and local levels to compare their performance and to build, evaluate and compare policies promoting accessibility on the basis of agreed measurements. Regional and local territories in particular can increase their technical capacity by using benchmarking results for developing and enhancing their actions. This can ease communication across levels and facilitate common accessibility-oriented policy frameworks.

Box 7. Tracking contributions to international commitments with accessibility-based benchmarks

The 2015 Paris Agreement aims at "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels" (UNFCCC, 2015). To this end, it recognises the need to considerably decrease anthropogenic GHG emissions in a way that is complementary with the social sustainability goal, such as reduction of poverty.

To meet this global goal and decrease transport-related emissions, cities have been developing strategies such as those inspired by the "Avoid, Shift, Improve" approach, i.e. a focus on avoiding the need to travel lengthy distances, incentivising a shift to less carbon-intensive modes, as well as improving average vehicle fuel efficiency. However, without ensuring access via alternative modes, these policies can generate negative social externalities, imposing burdens on vulnerable users while not significantly delivering greenhouse gas reductions. Benchmarking accessibility levels can contribute to assessing impacts of such policies from both the environmental and social standpoints at different levels. For instance, benchmarking accessibility levels can help assess negative distributional impacts related to transit-oriented developments or, for instance, ensure that policies increasing car costs in specific areas of a city are equitable.

The New Urban Agenda, agreed at the UN Habitat III conference in Quito, Ecuador, in 2016 recognises the need to move towards a logic of proximity by promoting "Better and coordinated transport and land-use planning, which could lead to a reduction of travel and transport needs" (target 114.c) (UN, 2016). No exclusive benchmark has been chosen to assess progress; instead, the New Urban Agenda calls for a joint effort from all relevant actors at the international, national and local levels to collaborate on generating relevant metrics. A benchmark that measures levels of access could be applied to evaluate the links between access to opportunities and social development in cities.

SDG target 11.2 further illustrates the potential for using accessibility indicators in measuring policy performance. This target, aiming to "provide access to safe, affordable, accessible and sustainable transport systems for all", is supported by the infrastructure-based indicator 11.2.1, measuring the proportion of the population with convenient access to public transport, by sex, age and persons with disabilities (UN, 2016). This indicator is based on the assumption that access to infrastructure relates to access to opportunities. While it is useful, measuring and tracking progress in achieving SDG 11, as well as other SDGs (e.g. SDG 4.3, "ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university"), could be enhanced by incorporating other indicators that measure access to jobs, health and education via motorised and non-motorised modes (OECD, forthcoming).

Source: based on UNFCCC (2015), ITF (2015), OECD (forthcoming).

Another potential use of the accessibility benchmarks is to improve funding allocation. Benchmarks can highlight differences in accessibility needs across territories and indicate where accessibility improvements are most needed or will be most effective. Quantifying and visualising these differences can even support decisions on resource allocation by international organisations and national governments. Benchmarking results could also facilitate cross-funding between different departments collaborating on accessibility-related policies. Providing transparency on how each partner's sector has benefited from the measure could potentially help secure funding.

Notes

1 Car dependency refers to development patterns that result from transport policies that favour automobile access and provide relatively inferior alternatives.
2 Location Efficient Urban Development refers to urban development pattern that is based on a principle of steering urban growth to locations which offer or have the potential to offer easy access through sustainable transport modes.

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Improving Transport Planning and Investment Through the Use of Accessibility Indicators

Accessibility of goods, jobs, services and other opportunities is a fundamental condition for ensuring the well-being of citizens. This report examines how accessibility indicators can be used to improve transport planning and investment with that objective in mind. It also identifies principles for accessibility-based decision making and discusses how accessibility indicators can be effectively operationalised.

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