



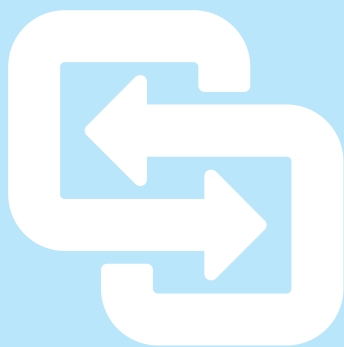
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Leading Sustainability

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Methodology and indicator
calculation method for

sustainable urban mobility



World Business Council for Sustainable Development
Sustainable Mobility Project 2.0 (SMP2.0)
Indicators Work Stream - 2nd Edition

Preface

The Indicators Work Stream (WS2) of the Sustainable Mobility Project 2.0 (SMP2.0) within the World Business Council for Sustainable Development (WBCSD) commissioned Oran Consulting to work with WS2 to define a set of indicators measuring the potential for sustainable mobility in cities. The application of these was verified with 6 pilot cities during the SMP2.0 process.

The indicator set is a tool for cities to evaluate the current situation of the mobility system, understand the evolution of the system over time and to evaluate the potential impact of selected solutions, for example those from the SMP2.0 solution toolbox.



Each indicator represents an aspect of mobility and is often interconnected with other indicators from the set. For instance, affordability and public finance are closely linked and so are congestion, travel time and air pollution. Holistically optimized solutions can be obtained while considering the interconnections: solutions might improve several related indicators in parallel.

At best, all indicators should be calculated (or, at a minimum, estimated) as this will enable holistic understanding of the current situation and lead to a robust decision making process. In addition to the main calculation methodologies SMP2.0 indicators set proposes alternatives methodologies to offer flexibility to match available data sets and city needs.

Although the indicators are not designed to compare the performances in sustainable mobility between cities, cities might use the indicator set to understand where they sit within the global scale and identify where they can further improve their local situation.



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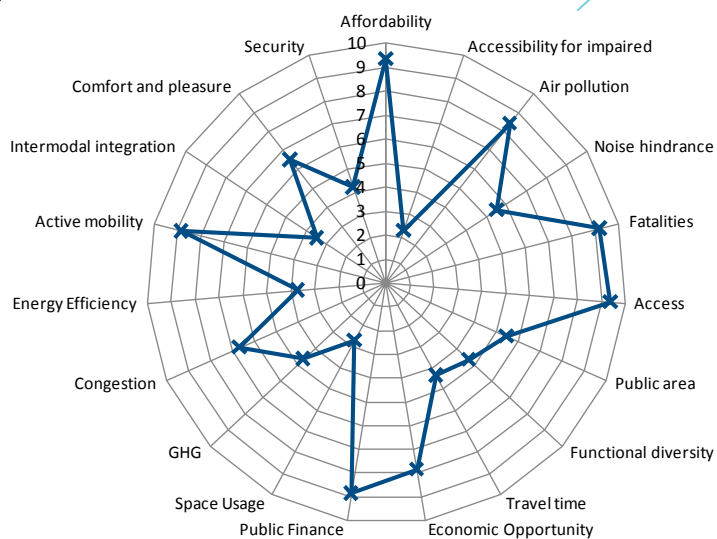
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Figure ES1: Example of the WBCSD SMP2.0 spider chart



Executive Summary

This report sets out the results of a piece of work to develop a comprehensive set of sustainable mobility indicators for cities. The indicators are described with SMART (specific, measurable, attainable, relevant, time-based) methodologies that will allow cities to perform a standardized evaluation of their mobility system and measure the improvements resulting from the implementation of new mobility practices or policies. If repeated over time this exercise will reveal the measures impacting the most efficiently on specific indicators and thus allow other cities to select the best measures in the context of a targeted action.



The indicators are presented as a comprehensive set spanning four dimensions of sustainable mobility. Three of the four dimensions are inspired by the pillars of sustainable development and refer to sustainable resource use and the impacts of mobility in cities:

- 1 Global environment
- 2 Quality of life in the city
- 3 Economic success

The fourth dimension has been added to consider the performance of the mobility system itself in the city:

- 4 Mobility system performance

The research carried out within the Sustainable Mobility Project 2.0 has resulted in the following set of 19 indicators:

- Affordability of public transport for the poorest group
- Accessibility for mobility-impaired groups
- Air polluting emissions
- Noise hindrance
- Fatalities
- Access to mobility services
- Quality of public area
- Urban functional diversity
- Commuting travel time
- Economic opportunity
- Net public finance
- Mobility space usage
- Emissions of greenhouse gases
- Congestion and delays
- Energy efficiency
- Opportunity for active mobility
- Intermodal integration
- Comfort and pleasure
- Security

The indicators have been calculated in Bangkok, Campinas, Chengdu, Hamburg, Lisbon and Indore in the frame of the SMP2.0 project. As a result from this test in cities, some of the original methodologies have been refined and some additional guidance has been added compared to the first edition.

Methodologies have been developed to include all modes of transport for passengers and freight and to be as attainable as possible for cities worldwide. A measurable parameter has been defined for each indicator and is described with the methodology to quantify it (chapter VIII). In addition to this report, a spreadsheet based calculation tool is available for interested city authorities. It has been developed to facilitate the calculation process based on the input data required.

The project proposes to represent the performance of the mobility system in the city in a “radar view” or “spider chart” to give a disaggregated overview of the sustainable mobility performance of the city. As such cities can identify their strengths and weaknesses in specific areas, find other cities having the desired strengths in order to identify mobility actions to implement and launch targeted actions.

Additional city mobility parameters (Occupancy rate, Motorization rate (4Wheels, 2Wheels), Modal split, Vehicle miles travelled per capita, Smartphone penetration, Availability of public transport cards, Car friendliness, Speed in the transport network) can be interesting to provide valuable insight into the city mobility and guide the solution selection and opportunities for development. They are described separately in Annex I in this report.

In addition, SMP2.0 believes that the issue of resilience in city mobility is a key aspect to consider while evaluating a mobility system and building mobility plans. As resilience can be defined in many different ways (time to escape, time to return to normal economic activity, etc.) and depends on the nature of the catastrophe and/or geography of the city, a city context-dependent discussion is needed that cannot be replaced by an indicator calculation. Points to consider in the discussion are described in Annex II in this report.

SMP2.0 discussions with the cities have clearly confirmed that calculating the whole set of indicators is the required first step. At best all the indicators are evaluated considering the metropolitan area, though for some indicators concentrating the focus on the urban core can also make sense (quality of public area, intermodal integration...). Disclosing the averages and disaggregation of the data into the different city areas, for different times of the day and for the different modes or consumer groups, provides deeper understanding of the mobility system and helps to target the solutions as precisely as possible.

Cities appreciated the SMP2.0 approach as it has stimulated a well-structured discussion, enriched by drilling down into the data and by taking other context data into account. Flexibility and guidance on how to choose the appropriate methodology have been proven to be success factors in the project.



This report documents indicator definitions, parameters and methodologies as well as guidance on possible approximations to be used by cities to identify their sustainable mobility performance. It contains practical information on the proposed methods for collecting data and the calculation of the parameters of each of the indicators. A spreadsheet has been developed to aid the calculation of the indicator scores based on the city data. The set of indicators is valid for cities at any stage of economic development.

The recommended surveys questions are contained in Annex III.

The structure of the report is as follows:

- I Introduction
- II Why work with indicators
- III Dimensions of sustainable urban mobility
- IV Overview of the indicators
- V Systems approach and indicator categories
- VI Indicator grouping
- VII Notes applied to all indicators
- VIII General methodology
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- Annex I WBCSD-SMP2.0 additional urban mobility parameters
- Annex II WBCSD-SMP 2.0 topic presentation
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II Why work with indicators

Why should cities work with the proposed indicators?

① A set of indicators with a sound basis

WBCSD SMP2.0 proposes a set of 19 indicators developed after a process of intensive work and with a core group of experts from different industries involved in urban mobility. The work group was backed by Oran Consulting, working closely with the Institute for Sustainable Mobility of Ghent University. An international and multidisciplinary group has contributed to the development of the indicators and international expert assessment meetings were organized at the Transforming Transportation Conference in Washington DC (16 January 2014) and at Organisation for Economic Co-operation and Development (OECD) secretariat in Paris (17 June 2014).

WBCSD-SMP2.0 collaborated with 6 pilot cities: Bangkok (Thailand), Campinas (Brazil), Chengdu (China), Hamburg (Germany), Indore (India) and Lisbon (Portugal) to test the validity and practicality of the indicator set. That exercise led to some methodology refinements (refined methodologies are the changes in this edition compared to the first one) and led to the conclusion that a small group of urban mobility parameters can enhance the understanding of the result of the indicator set for mobility planning (annex I).

② A set of indicators giving the state of sustainable mobility in the city

Cities need to assess the complete set of indicators in order to obtain a comprehensive assessment of their mobility performance over the full scope of the sustainability dimensions. By using the full set of 19 indicators cities can identify where the strengths and weaknesses lie in their mobility system. The scale provided by SMP2.0 is from 0 to 10 and based on the extremes observed worldwide. As such, the city can use the indicator scores to identify in which area to work for improvement. Studying the disaggregated data is recommended for cities to identify the geographical areas (corridors, neighborhoods, etc.) and specific modes of public transport vs private vehicles, or passenger vs freight mobility) for action.

③ A set of indicators allowing for the identification of the most appropriate solutions

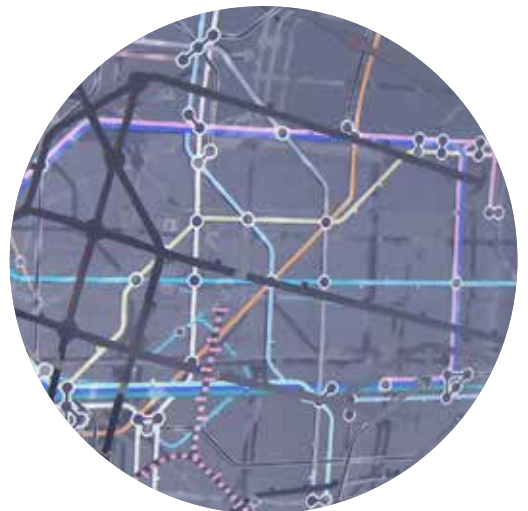
SMP2.0 project has created an inventory of worldwide best-practices and emerging solutions in which each mobility solution has been assessed by its impact on the 19 indicators. Having selected the indicators to work on, the city can match these indicators with a reduced set of solutions and ensure robust mobility planning addressing the range of city priorities.

④ A set of indicators allowing for the monitoring of progress

By calculating the indicators at regular times (e.g. every year) cities can measure in which areas and to what extent they made progress towards sustainability and achieving a better performing urban mobility system.

⑤ A set of indicators that is technology and mode neutral

Special care has been taken to ensure that the indicator values are not influenced by a technology or a mobility mode itself. Only the environmental, social or economic impact on the variables used to calculate the indicators will change the indicator value. It allows the city to choose the solutions best suited to its economic, social, environmental and technical resources.



III Dimensions of sustainable urban mobility

“Sustainable mobility is the ability to meet society’s need to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological values, today or in the future.”

(Source WBCSD, Mobility 2030: Meeting the challenges to sustainability, 2004)

The definition of the sustainable mobility concept can be drawn based on the dimensions commonly used in sustainability: planet, people and prosperity (or profit). Applied to urban mobility, the dimensions considered by SMP2.0 are:



G

Global Environment

Global environment (**G**) refers to the global scale, i.e. mobility impacts that occur far beyond the city limits, and is focused on long-term environmental aspects (such as GHG).





Q

Quality of Life

Quality of life (**Q**) refers to the city or local scale and the short-term (direct impacts) on social aspects of urban life (such as health or fatalities and security).

E

Economic Success

Economic success (**E**) refers to the economic aspects at the city scale (such as public finance related to mobility).

S

Mobility System

Apart from external inputs (resources and materials) and outputs (impacts) of the mobility system (with the three above-mentioned sustainability dimensions) a fourth category of indicators refers to the **performance of the mobility system (S)** itself. This performance might have consequences for the input or output of the mobility system on all three sustainability dimensions.



IV Overview of the indicators

A set of 19 indicators has been identified to comprehensively describe sustainable mobility in cities. They allow assessment of the performance of cities worldwide and for any stage of economic development.

provokes a waste of time for the passenger (Q) and has high associated costs (E). We have represented the set of indicators and the two main dimensions associated with each indicator in the table below.

The indicators may impact on two, three or even four sustainable mobility dimensions. For example, Congestion increases Air pollution (Q),

Set of 19 indicators for the sustainability of urban mobility	Short names of indicators	Dimensions	
Affordability of public transport for the poorest people	Affordability	S	Q
Accessibility for mobility impaired groups	Accessibility for impaired	S	Q
Air polluting emissions	Air pollution	Q	
Noise hindrance	Noise hindrance	Q	
Fatalities	Fatalities	Q	
Access to mobility services	Access	Q	
Quality of public area	Public area	Q	
Urban Functional diversity	Functional diversity	Q	E
Commuting travel time	Travel time	Q	E
Economic Opportunity	Economic Opportunity	Q	E
Net public finance	Public Finance	E	
Mobility space usage	Space Usage	G	E
Emissions of greenhouse gases (GHG)	GHG	G	
Congestion and delays	Congestion	G	S
Energy efficiency	Energy efficiency	G	S
Opportunity for active mobility	Active mobility	G	S
Intermodal integration	Intermodal integration	S	
Comfort and pleasure	Comfort and pleasure	S	Q
Security	Security	S	Q

Table.1: Overview of the 19 Sustainable Urban Mobility Indicators indicating the dimensions of the sustainability of the mobility system. Source: Oran Consulting for WBCSD SMP2.0, 2014

Three dimensions refer to the sustainability of the resource use and/or the impacts of mobility in the city:

- G Global environment
- Q Quality of life
- E Economic success
- S Mobility system performance



Among the indicators related to economic success, Public finance is directly related to the budget of the city, Commuting travel time is related to economic success as every minute employees lose in traffic jam can be assessed as an economic loss (lack of productivity), finally Economic opportunity as defined here is related to economic success as it counts the accessibility to jobs and education centers. Space is a scarce resource for cities and depending how space is well-used or misused it can contribute to the city prosperity or not.

The impact of mobility on quality of life is becoming increasingly recognized by citizens and city authorities. A good mobility system can really improve citizen's everyday life, providing pleasure while moving and releasing time for other activities. The indicator set mirrors this well as 12 out of the 19 indicators appear to impact on the dimension quality of life. The most obvious indicators in that dimension are Fatalities and Air polluting emissions as they are direct threats to human life. Other indicators impact quality of life really directly such as Affordability and Accessibility of the transport, Noise, Commuting travel time, Quality of public area. Indeed for anyone life is more pleasant when mobility is cheaper, efficient and accessible, and in a quiet city having opportunities for social interaction. Finally, Functional diversity is impacting on the quality of life of the citizen as it reflects the proximity of diverse city functions (lodging, shopping, education, healthcare ...).

GHG emissions contribute to the greenhouse effect and thus impact the Global Environment. Energy efficiency and Congestion will influence the amount of GHG emissions thus also impact global environment. Finally, as the Opportunities for an active mobility are opportunities to reduce the emissions of GHG this indicator is also impacting global environment.

The indicators assigned to the dimension mobility system performance are for SMP2.0 the necessary components that each mobility system should consider and optimize. As such there is Affordability, Accessibility for the impaired, Intermodal integration, Comfort and pleasure, Security, Congestion, Energy efficiency and Opportunity for active mobility.

In summary, the respective dimensions are covered by the following indicators:

- **Global environment (G)**
 - Mobility space usage
 - Emissions of greenhouse gases
 - Congestion and delays
 - Energy efficiency
 - Opportunity for active mobility

- **Economic success (E)**
 - Urban functional diversity
 - Commuting travel time
 - Economic opportunity
 - Net public finance
 - Mobility space usage

- **Quality of life (Q)**
 - Affordability of public transport for the poorest group
 - Accessibility for mobility-impaired groups
 - Air polluting emissions
 - Noise hindrance
 - Fatalities
 - Access to mobility services
 - Quality of public area
 - Urban functional diversity
 - Commuting travel time
 - Economic opportunities
 - Comfort and pleasure
 - Security

- **Performance of the mobility system (S)**
 - Affordability of public transport for the poorest group
 - Accessibility for mobility-impaired groups
 - Congestion and delays
 - Energy efficiency
 - Opportunity for active mobility
 - Intermodal integration
 - Comfort and pleasure
 - Security



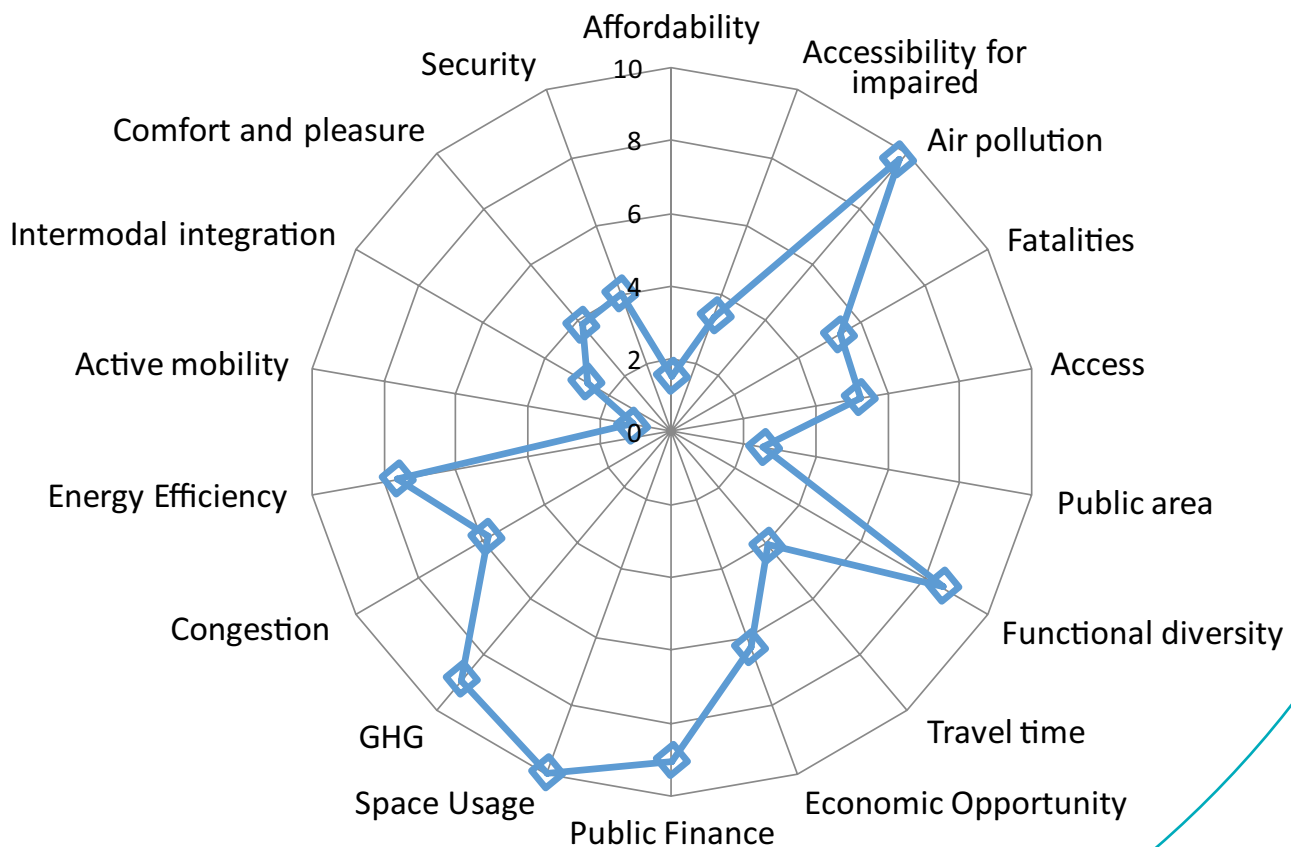
The benefits of working with dimensions and the mobility system approach for the city are explained in the next two chapters of this report. In these chapters, the dimensions indicated for each of the indicators in table 1 are explained further in detail.



The score (0 to 10) of the indicators are calculated based on the parameter value selected to describe the indicators. SMP2.0 proposed to represent the scores of the 19 Indicators on a spider chart. By giving this disaggregated overview of the sustainable mobility performance, the city can identify its strength and weaknesses.

Figure 1: Spider chart for 19 Sustainable Urban Mobility Indicators for Indore. Calculations were carried out before refinement of the methodologies, indicator results from survey: 5=satisfied. Noise isn't present in this spiderchart as Indore chose not to calculate it.

Indore Mobility Indicators

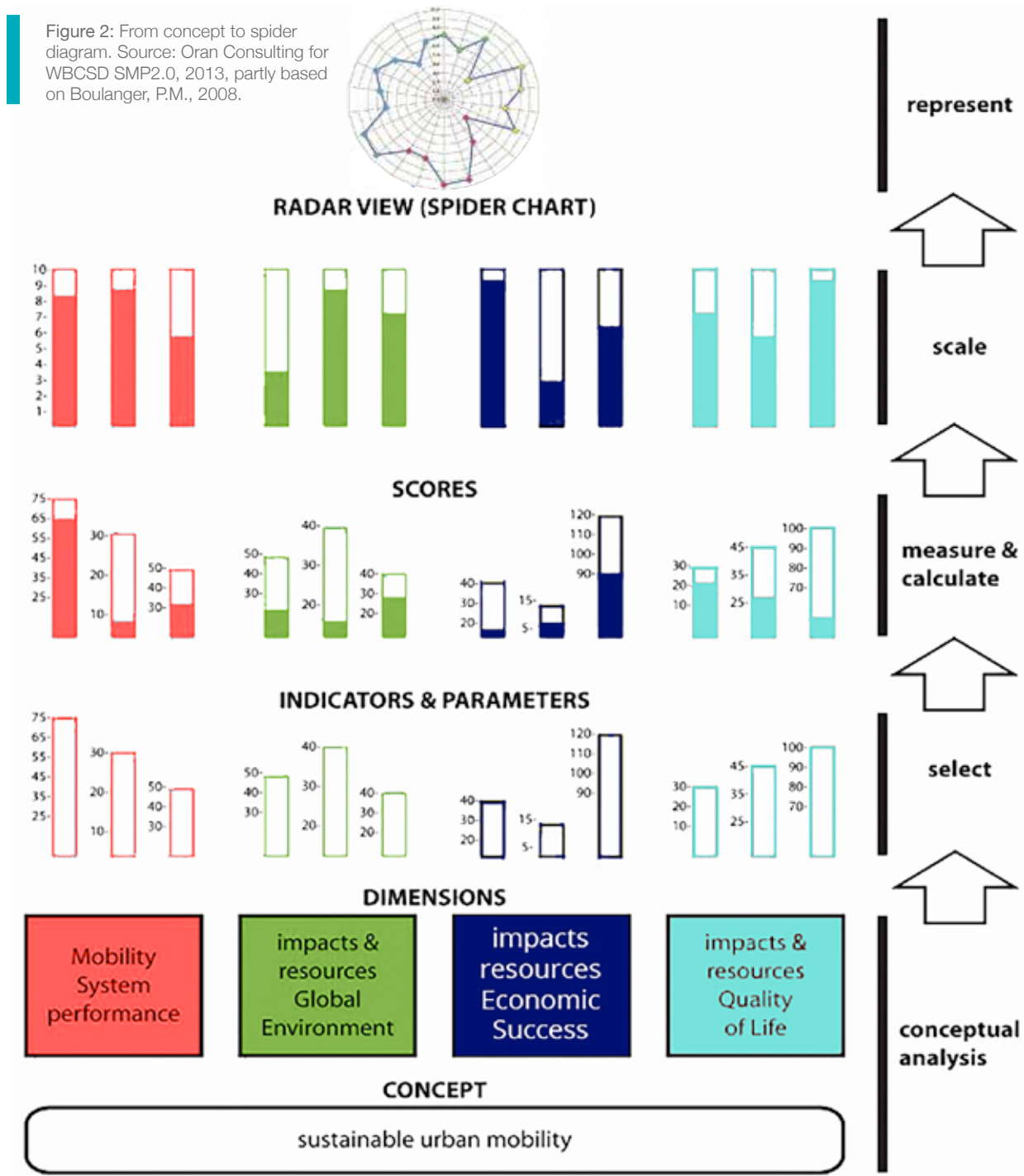


Furthermore, the spider chart or radar enables the observation of how indicators are interconnected in the sense that it is possible to see how some solutions impact simultaneously on several indicators. For example, a BRT decreasing Congestion is expected to also positively impact on GHG, Air pollution and Travel time.

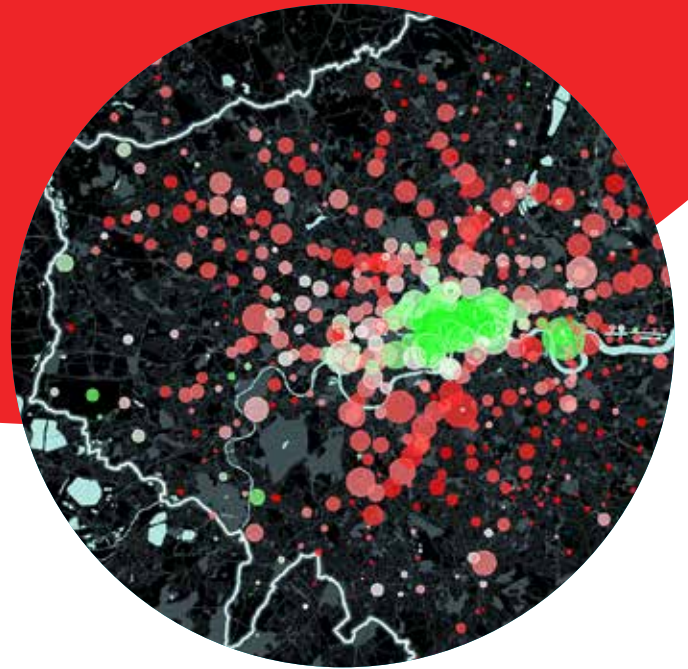
that describe sustainable mobility in cities in a comprehensive way. This selection includes finding out how to parameterize each of the indicators: i.e. defining how to quantify them (selecting a unit of measurement for the parameter and composing a formula to calculate it). The next step is to measure and calculate the indicator values. After calculating the indicator values, they need to be standardized into scores based on a standardized scale. The scale used here, adopted by the WBCSD, is from 0 (minimum performance) to 10 (top score). Finally, they can be presented in a spider chart, offering a radar view of sustainable urban mobility performance.

Figure 2 depicts the process developed by SMP2.0 for cities to evaluate their sustainable mobility performance.

More specifically, figure 2 shows the theoretical path from the “sustainable urban mobility” concept to a visualization of its outcome. It starts by identifying the dimensions and the selection of a set of indicators

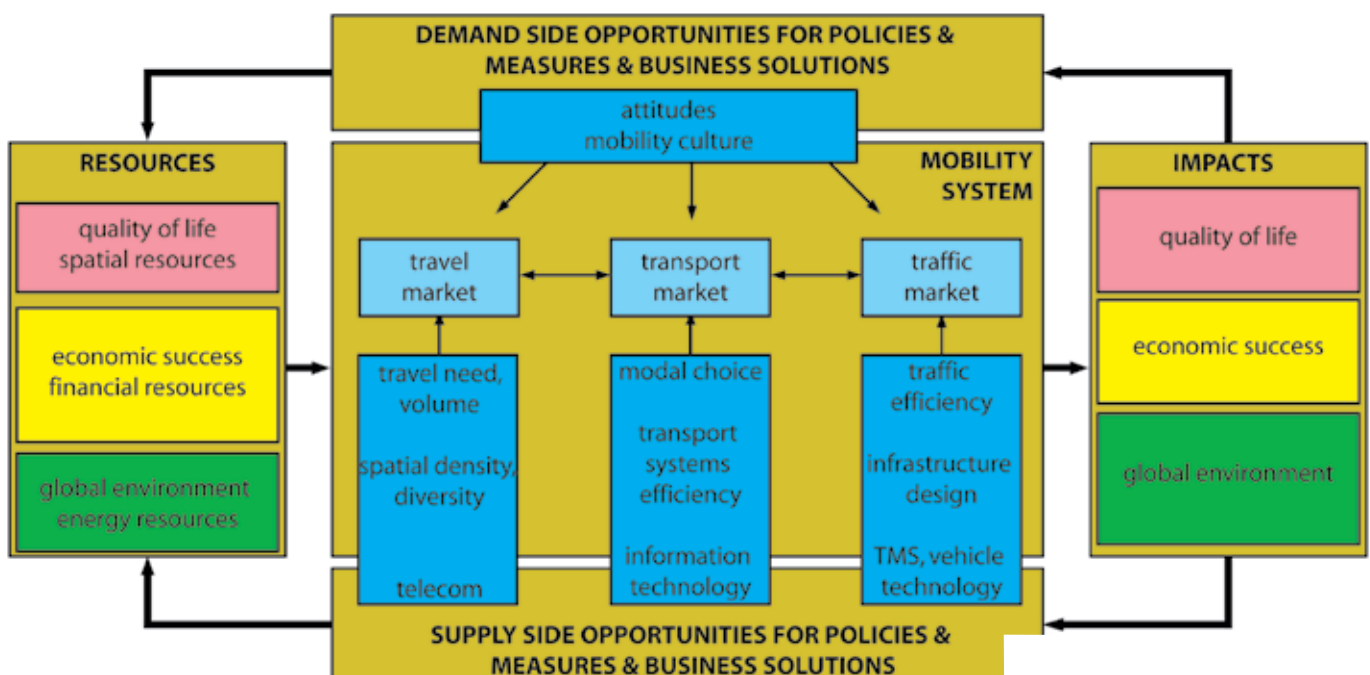


V Systems approach and indicator categories



Sustainable mobility indicators help to disaggregate the complex system of mobility in cities. This system is characterized by its travel, transport and traffic patterns. It is shaped to provide supply corresponding to demand with the best mobility performance possible, using the least amount of resources, and provoking the least negative impacts possible (figure 3). By nature, the indicators developed by SMP2.0 are related to the different components of the mobility system. Their relation is represented in figure 4. The resulting scheme is useful for cities when looking for a broad scope of possible solutions and measures; when possible, interrelations between parameters must be identified.

Figure 3: Mobility system approach, a simplified conceptual model developed for WBCSD by D. Lauwers and G. Allaert. Source: Oran Consulting for WBCSD SMP2.0, 2013



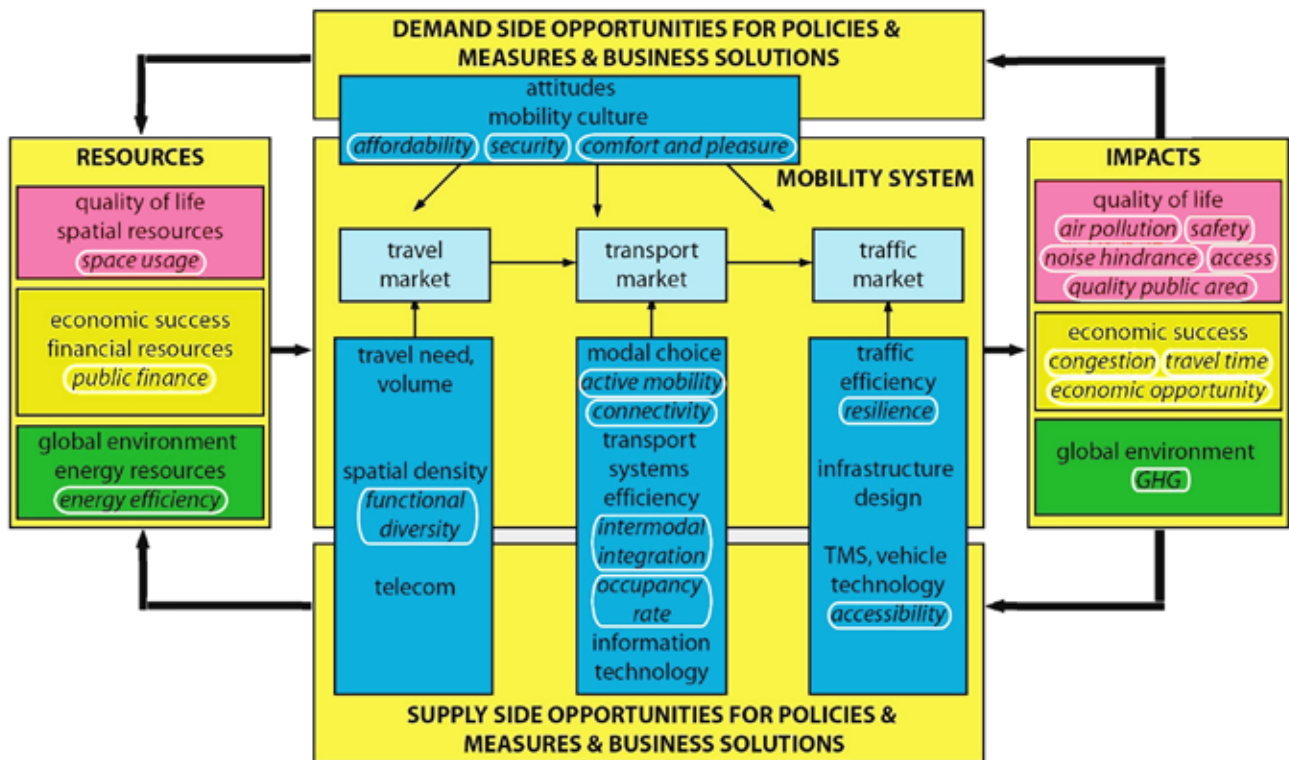


Figure 4: Indicators within the mobility system approach, scheme developed for WBCSD by D. Lauwers and G. Allaert, source oran consulting for WBCSD SMP2.0 IWS, 2014

The indicators are well distributed among the different sub-dimensions of sustainability. Table 1 presents the indicators and the two main dimensions on which they impact. For simplicity a unique dimension is associated with each indicator in figure 4.

Figures 3 and 4 rely on the following definitions:¹

The **travel** market is the market where the demand for activity and the supply of activity opportunities in space and time create travel patterns.

The **transport** market is the market where the demanded travel pattern and the supply of transport options come together in a transport pattern that assigns passenger and goods trips to vehicles and transport services..

The **traffic** market is the market in which the required transport patterns are confronted with the

actual supply of infrastructure and their associated traffic management systems, information systems, etc.

The difference between the three markets is relevant to describing the supply-side opportunities for policies, measures and business solutions to change the performance of the mobility system (bottom of the schemes in figures 3, 4 and 5).

A first category of policies, measures and solutions affects the travel market by influencing the need for travel, for example by changing the spatial pattern of living, working, shopping and recreation by emphasizing the advantages of spatial proximity. Structuring the timing of trips, the flexibility of working hours, the introduction of shorter working weeks, the distribution of holiday periods

¹The description of the three market model is partly based on: Immers, B. (2010), "Transportation System Analysis", Lecture, University of Leuven, Leuven.

A second category of policies and solutions affects the transport market. This can be obtained by influencing **modal choice**. Although cars will continue to be an essential part of the urban mobility system for the foreseeable future, there are possibilities to increase both the supply and the attractiveness of alternative modes of transport and the intermodal connectivity between road and other modes in order to facilitate intermodal (combined) trips. Increasing the quality of the existing public transport system in terms, for example, of comfort, information and service can contribute to this end. The role of the existing collective transport system can also be enhanced by the introduction of alternative forms of public transport such as shared cars or shared bikes. The transport market will also be affected by influencing **transport efficiency**. Policy and solutions in this area should aim to optimize the operation of vehicles both for passenger transport and for goods transport.

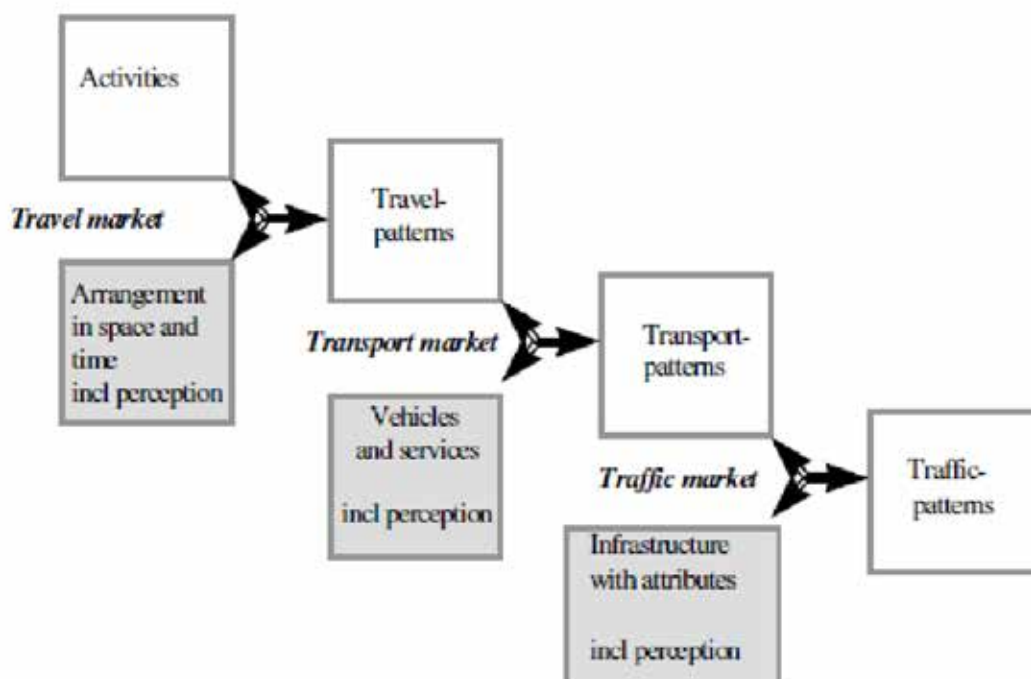
Opportunities for policies and solutions in the traffic market consist of influencing **traffic efficiency**. Traffic efficiency refers to the extent to which the potential capacity of the existing traffic system is exploited. Here, modern traffic management systems (TMS), usually based on telematics applications, are significant. Examples are the provision of dynamic route information (coupled with incident- and tailback-detection systems), ramp metering and incident management (based on rapid intervention). Improved infrastructure design also affects the traffic market. Many of the measures developed by the cities themselves aiming to increase the sustainability of the mobility system are based on improvements in infrastructure design. Additionally, the traffic market is the most prominent area for industries to develop solutions that broadly affect sustainability: resource use can be optimized using vehicle technology

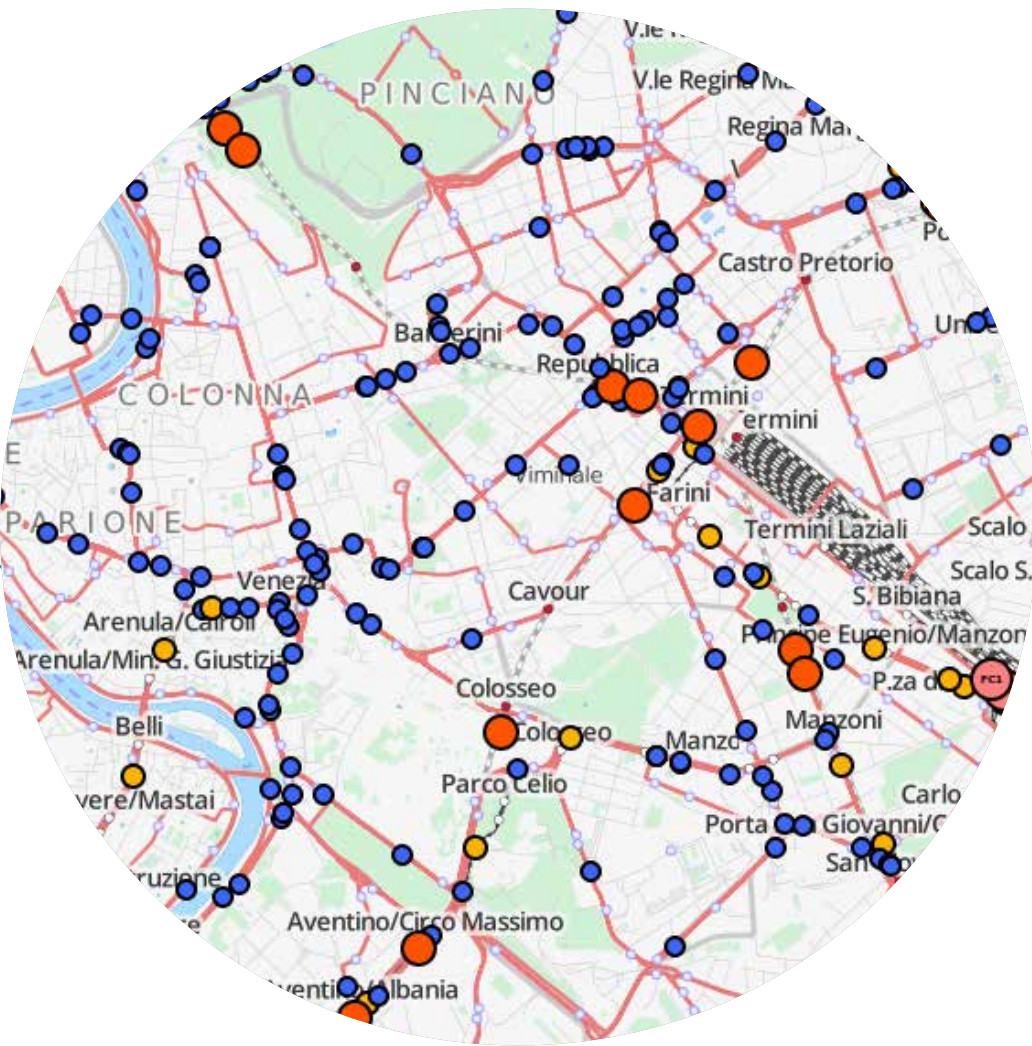
(engine type and efficiency, design, computer-driven performance, etc.), infrastructure design, traffic management systems, etc.

The top of figure 3 shows that the mobility system in a city is influenced by the attitudes of mobility consumers and the mobility culture. These features offer **opportunities for demand-side policies, measures and business solutions**.

The sustainable development of urban mobility systems is only possible when the necessary measures are incorporated institutionally into society. The determining factors in this area are the attitude of the consumers towards the attainment of sustainable targets and towards mobility, resulting in mobility culture(s). Mobility culture refers to attitudes towards the travel market. Consumers make their own decisions based on the perception of the advantages and disadvantages surrounding travel, transport and traffic choices. Pricing, regulations and education are the main categories of opportunities for the development of mobility policies.

Figure 5: The three markets model. Source: Egeter, B and O. van de Riet, 1998, Systeemdiagram voor het beleidsveld vervoer en verkeer (System diagram for the policy area transport and traffic), Delft, TNO Inro, report nr 1998-02.





VI Notes applied to all indicators

1 Selection process

The list of 19 indicators is based on a selection starting from a long list identified by the Indicators Work Stream (members of different industries). In order to avoid redundancy, the following criteria were applied by the selection:

- *Fairness*: including both positive effects of mobility (e.g. accessibility) and negative impacts (e.g. noise hindrance).
- *Completeness*: the set of indicators has to measure all relevant aspects for evaluation of the sustainability of the urban mobility.
- *Technology neutral*: not favoring one technology over another, existing or to come.

- *Mode neutral*: not favoring any mobility mode

Different methodologies can be used to quantify the indicators. One main goal of this work was to propose the most appropriate methodologies that would be specific, measurable and attainable by the largest number of cities. Regularly assessing the indicators following the same methodology will allow cities to identify their improvements. Additionally, if a common methodology is used across several cities it will enable the building of a valuable database demonstrating which cities succeed well in which mobility aspects and this could be linked further to the best practices they are using.

The SMART method was used to identify the most appropriate parameters:

- Specific:** measures what should be measured, based on the indicator definition
- Measurable:** the parameter can be quantified with sufficient accuracy
- Attainable:** using input data that are readily available or can easily be collected
- Relevant:** result-oriented (related to solutions)
- Time-based:** can be frequently updated in order to monitor evolutions.

After theoretical development, the indicators have been calculated in six cities worldwide (Bangkok, Campinas, Chengdu, Hamburg, Indore and Lisbon). As a result from this test in the cities:

- The two indicators on intermodality (physical interconnections, and quality of the intermodal stations, information etc.) were grouped together in a single indicator assessed by survey.
- The indicator occupancy rate has been moved into the parameter section because the assimilation of all modes and passenger and freight in a single index was too hard to interpret and it is not possible to therefore define what would be an optimum occupancy rate.
- It appeared that the indicator resilience would be better considered in a dialogue with the city rather than as a single indicator because of a high dependence on local parameters; the nature of the likely catastrophe; the geography, etc.
- The calculation methodology for Economic opportunity was modified.
- The scaling of some indicators was reviewed, more notably for congestion
- Annex I has been introduced to group together additional city criteria that have been selected for their relevance to assess the city opportunities for development and guide the solution choice.
- Annex II explores how to bring resilience to the discussion table with the cities

2 Scope of the indicators

Air transport and sea shipping are excluded. In most cities (the sustainability aspects of) these modes are beyond the scope of urban governance.

Unless otherwise stated, the indicators are calculated as **values over the year** (12-month period).

3 Value and scaling of parameters

It is the target of SMP2.0 to provide indicators which are not influenced by the physical characteristics of the city (e.g. population, area...) but by possible improvement actions.

Parameter values are expressed in different scientific units (e.g. number of fatalities per annum per capita, MJ per annum per vehicle-kilometer, etc.). In order to have a standardized reference value, all parameters are recalculated to a **scale of 0** (most

negative score) **to 10** (most positive score). The base scaling (calibration) of the indicators were inspired by data from Belgian cities (e.g. Brussels) and Lisbon or from literature research, a deductive choice or long term sustainability goals (e.g. the World Health Organization's Zero Vision on fatalities, i.e. no fatalities at all in the transport system due to accidents). Some of the scaling as presented here has been refined based on the experience in the 6 demonstration cities. .

A **well balanced scaling** of the parameters is necessary:

- To identify stronger and weaker performance among the different indicators and the sustainability mobility dimensions in a city.
- To identify the position of the city for a certain indicator compared to one or more other cities the city wants to refer to.
- To validate the impact of solutions on the parameter values. As important improvements on a small scale can be lost in the bigger entity, the scale span can be adjusted or the indicator can be calculated on a smaller focus area. This will make it possible for the city to test the relevance of the possible implementation of different solutions and to make choices between the solutions. Comparing parameter values before and after the implementation of solutions will also allow the city to monitor the effects of these solutions.

The parameter values represent an **average score** over different areas (city districts, transport corridors) in the city. They also show the overall position of the city for a certain indicator in the process of becoming more sustainable. As a consequence, the sensitivity of the solutions might be (too) limited. In view of the **solution evaluation**, the scaling can be adapted:

- Possibility to intentionally adjust the scale range (default span of values is still available)
- Possibility to reduce the measured area in the city (e.g. critical zone or corridor only). This means that only a selection of data (e.g. field measurements, population surveys, etc.) has to be considered. In this case, it is necessary to check the validity of the parameter.

Working with averages also **masks the extreme values** that might be most relevant in order to identify the most appropriate solutions for a city. For example, apart from the average value of the travel time, the variation in travel time, during a certain time period (months, weeks) on a corridor might be at least as relevant, as this variation shows the predictability of the travel time. This predictability will be a factor of extra time precautions transport users will include in their trip planning. Additionally, for several indicators the city can break down the calculations into different groups of consumers or citizens or into transport modes. This tailor-made evaluation can be used to target specific issues.



VII General Methodology

1 Calculation methodology for the indicator parameters

The next chapter gives a definition for each of the indicators and a parameter to measure its sustainability score. These parameters are obtained via formulae that are also described. A detailed description of what to do for each of the parameters can be found in the next chapter.

A spreadsheet for the indicators is available.

a Types of variables

There are seven types of variables:

- 1 **Common input variable:** these input are variables, such as the number of inhabitants of the city (called 'capita' in the parameter formula), that are used in different indicator parameter calculations
- 2 **Indicator-specific input variable:** these variables are used in a formula for one of the indicators, for

example number of fatalities to calculate the level of transport safety for the indicator describing this aspect of the sustainability of the city transport

- 3 **Default value variable:** these variables are present in the formulae to calculate the indicator value. A default value is proposed by WBCSD SMP2.0. The default value can be replaced with a city-specific value if cities have more appropriate values available (because of regional differences in, for example, the energy content of one m³ of natural gas used in the country).
- 4 **Conversion value variable:** fixed values based on scientific research or scientific relations between some of the other variables.
- 5 **Output variable:** the result of the formula calculation, indicating the parameter value for the sustainability indicator concerned.
- 6 **Calculated value:** intermediate calculation results, to be used in later in the indicator calculation process.
- 7 **Informative input variable:** not used in the parameter calculation, but can be used for local, city-relevant calculations.

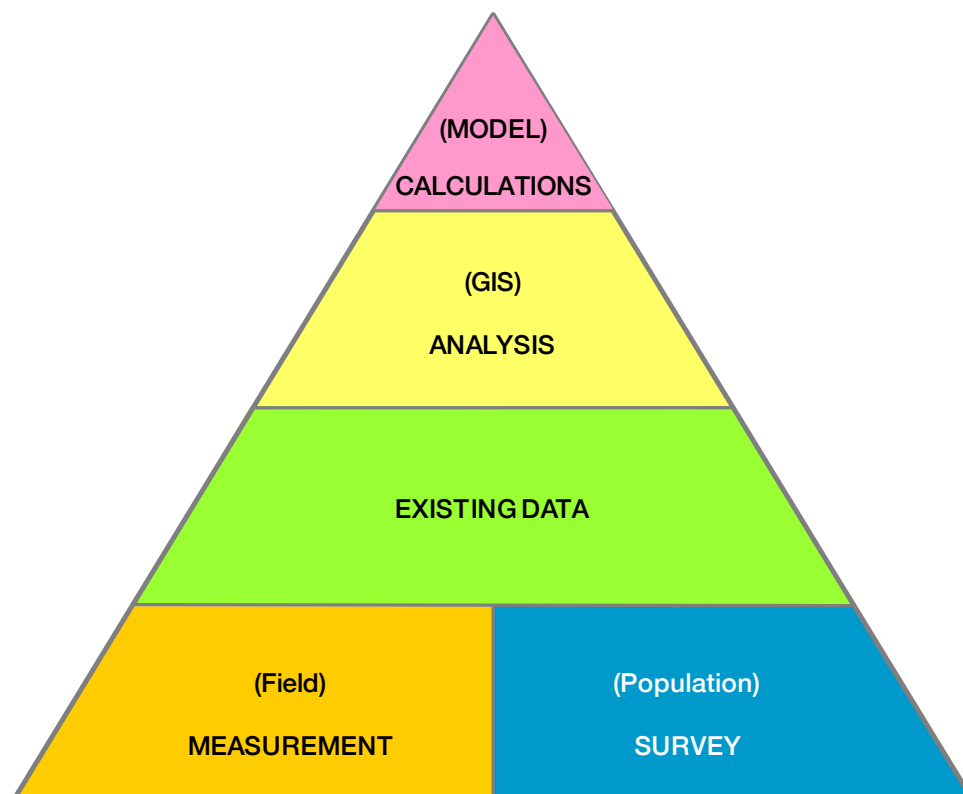
b Indicator score calculation

From the parameter value calculation, the indicator score is decided from its position between the best (10) and the worst (0) parameter values as recommended by SMP2.0. A score of 10 will therefore indicate a sustainable performance for the city in that aspect.

2 Methodologies for data gathering

There are five methodologies for data gathering. They are represented in figures 6 and 7. Figure 6 shows the logical relationship between the different methods:

Figure 6: Overview and logical relation between data gathering methodologies.
Source: WBCSD SMP2.0, 2014



Input data for parameter calculations are originally based on either field measurements (with technical instruments such as traffic counting devices) or population surveys (e.g. asking transport users for their average commuting travel time). Some of these data are stored in existing databases, other data need some geographical analysis (e.g. calculating the length of motorways in the city based on maps). Specific software (geographical information systems – GIS – software packages) is preferred or is in some cases even necessary in order to execute such an analysis. Sometimes traffic (simulation) model have to be used to calculate some traffic or transport features (e.g. vehicle-kilometers travelled on certain types of roads).

calculations based on this raw data (commonly using traffic models). Cities that cannot (afford to) deploy such software packages have to rely on the unprocessed data sources as a second option. A third option is to use best guess method to find an approximate value for (some) input data. Of course the reliability and even the relevance of indicators based on this third method can be rather doubtful. It is advised to check the sensitivity of the indicator result to variances in any input data that was estimated under the third option.

The grouping of data sources can be found in figure 7. The scheme represents the relationship between the input data and the parameters formula (as available in the spreadsheet). For cities the most relevant difference between the five types of data sources appears between unprocessed data and processed data. Unprocessed data can be obtained directly from existing databases, surveys or measurements. Processed data result from the analysis of raw data (commonly using GIS) or

Figure 7: Overview of the typology of input data sources. Source: WBCSDSMP2.0, 2014

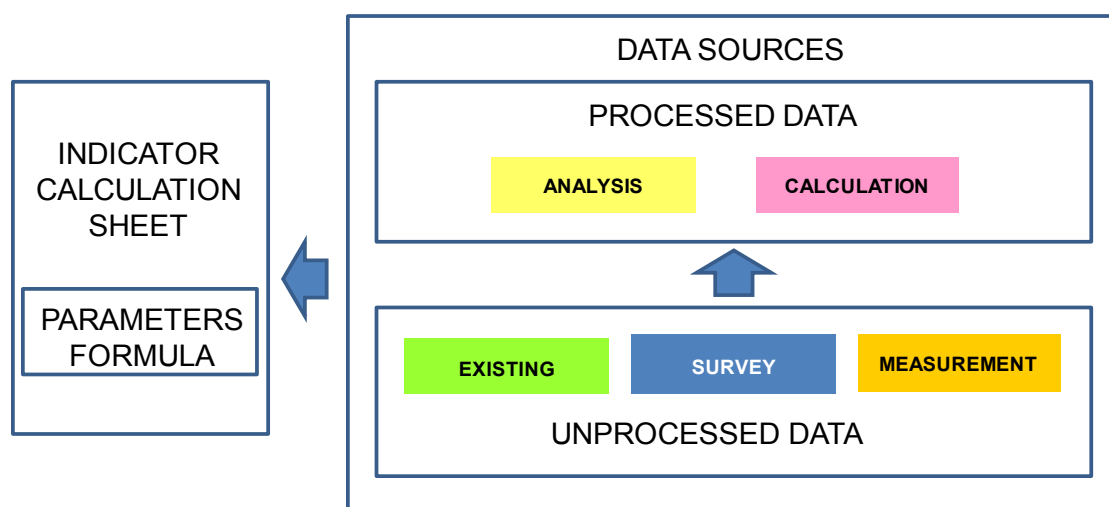


Figure 8 presents an overview of the typology of most appropriate input data sources for all 19 indicators as well as the scaling. However, a more detailed description can be found in the next chapter, which deals with the methodology and scaling of each of the indicators separately. In the following pages the different types of input data sources are described further in general, specifying what type of data source is most appropriate for each of the indicators.

Figure 8: Overview of the typology of input data sources for all 19 indicators, source: WBCSD SMP2.0 IWS, 2014

List of indicators	Input	Scales
Affordability of public transport for the poorest group	Exist	
Accessibility of mobility-impaired groups	Survey	
Air polluting emissions	Calc	
Noise hindrance	Measure	
Fatalities	Exist	
Access to mobility services	Analysis	
Quality of public area	Survey	
Urban functional diversity	Analysis	
Commuting travel time	Survey	
Economic opportunity	Survey	
Net public finance	Exist	
Mobility space usage	Analysis	
Emissions of greenhouse gases	Calc	
Congestion and delays	Measure	
Energy efficiency	Calc	
Opportunity for active mobility	Analysis	
Intermodal integration	Survey	
Comfort and pleasure	Survey	
Security	Survey	

a Using existing databases

The use of existing databases is inherent in all methodologies. Coefficients can be found in existing databases for some of the indicators. In some cases authoritative international sources have to be used. For others, specific national or city databases give more relevant or sometimes the only suitable figures.

The following indicators are partly based on coefficients from international or national databases:

Air polluting emissions (international database)

Emissions of greenhouse gases (GHG)

Energy efficiency (international database)

The indicators below are mainly based on city (or regional-specific) databases and are expected to be available because they have to be reported in the frame of monitoring the performances of cities, regions or national economies:

Affordability of public transport for the poorest quartile

Fatalities (city or regional/national database)

Economic opportunity

Net public finance

The data for these four indicators are grouped in a first main category referred to further on as “existing data” methodology (M1).

The number of inhabitants, surface of the city (region), and distance travelled are specific data used as a denominator in the formulas.

In traffic models and GIS calculations, specific data (e.g. on infrastructure networks) need to be integrated. These methodologies are described further on.

Table 2: Example of databases used when calculating the indicators in our 6 cities

Indicators	Example of data sources
Affordability	Public transport companies report; National/City census; Office of statistics
Air pollution; GHG; Energy efficiency	City data: vehicle park; Environmental agencies; National/City emission report; Standard regulations on emissions/km
Congestion	(if not field measurement) Online app or navigation devices
Noise	(if not field measurement) Office of statistics
Fatalities	Statistics of Road Traffic Accidents; National/City census; World Bank/UN Global Indicators databases
Access	National/City census; Office of statistics
Functional diversity	Urban planning office;
Public Finance	Public transport companies sustainability report; City budgets
Space Usage	Urban planning office
Active mobility	Urban planning office; Mobility office;

b Surveying

A population survey is proposed for the following indicators:

Accessibility for mobility-impaired groups
Quality of public area
Commuting travel time (if traffic model is not available)
Intermodal integration
Comfort and pleasure
Security
Economic opportunity

The data for the above-mentioned indicators are grouped in a second main category referred to further on as “survey” methodology (M2).

For the indicators below if the distances travelled with different traffic modes are not available via traffic modelling or in existing databases, a survey has to be carried out following the same methodology as for the “survey methodology”:

Air polluting emissions
Emissions of greenhouse gases
Congestion and delays
Energy efficiency

Topics to be covered in the surveys are described later in the individual indicator descriptions and the complete survey questionnaire can be found in Annex III.

Some general common aspects of the methodology are described here.

- The target population is users and non-users of different transport modes.
- Only one person per family, per shop, education institution or work place is to be questioned. It has to be clearly marked if the interviewee is an inhabitant, visitor or commuter.

For general surveys the sampled populations should be a mix of inhabitants, tourists and commuters that somewhat reflects the dynamics in the city. The sampling for the questions related to the impaired should be 100% inhabitants.

Target groups

Most topics are asked to the total population (in a broad sense: not only inhabitants, but even so commuters, visitors, tourists ...):

Quality of public area
Commuting travel time
Economic opportunity
Intermodal integration
Comfort and pleasure
Security

One indicator is targeted at specific groups:

Accessibility for mobility impaired groups
Elderly people (65+)
Pregnant women
Disabled:
Physically disabled
Visually disabled

The identification of these mobility-impaired groups is based on international common classifications, e.g. those used in the European project “CIVITAS” on urban sustainable mobility. Apart from adapted facilities for impaired groups, other specific design criteria can be put forward, for example for pedestrians carrying (shopping) bags or packages or for people pushing prams.

Some cities and public transport companies are concerned about providing facilities to carry bikes on public transport carriages.

Minimum size of the sample to represent the target population

To determine the size of the surveying sample, these variables should be considered:

- Acceptable margin of error **E** – is a statistic expressing the amount of random sampling error in a survey’s results or the amount of error that can be tolerated. A lower margin of error requires a larger sample size, while a margin of error that is too large gives less confidence that the survey reported results are close to the “true” figures. Five percent (5%) is a common choice for the acceptable margin of error.
- Confidence level **c** – the confidence level is the amount of uncertainty that can be tolerated. This number can be any percentage less than 100%, but the most common levels of confidence are 90%, 95% and 99%. Of these three, the 95% level is used most frequently. Higher confidence levels require a larger sample size
- Response distribution **r** – for each question, what are the expected results? If the sample is highly skewed one way or the other, the population probably is too. If unsure, use 50%, which gives the largest sample size.
- Size of population **N** – the population is the complete set of people that you want to understand and therefore the people to choose from the random sample. The sample size does not change much for populations larger than 20,000.

Size of sample is defined as:

$$n = \frac{N \cdot x}{(N - 1) \cdot E^2 + x}$$

Where x is defined as:

$$x = Z \cdot \left(\frac{c}{100}\right)^2 \cdot r \cdot (100 - r)$$

And Z is the standard score.

Value $Z \cdot \left(\frac{c}{100}\right)^2$ represents critical value for

the confidence level c.

E can be defined as:

$$E = \sqrt{\frac{(N - n) \cdot x}{n \cdot (N - 1)}}$$

Table 3 shows the sample sizes based on population size.

Margin of error 5%; confidence level 95%; response distribution 50%	
Population size	Sample size
1000	278
5000	357
10000	370
50000	382
100000	383
500000	384
1000000	384
1500000	385
2000000	385
5000000	385
10000000	385

For example, consider the city of Zagreb, Croatia, which has an overall population in its metropolitan area of 1,107,623 inhabitants and the goal is to survey based on a sample that would represent the whole population. Since we do not know the expected results for each question, r is defined to be 50%. For an acceptable margin of error E, the value of 5% is selected and confidence level c is set to be 95%, as this is the amount of uncertainty that we are able to tolerate. Based on these data, the sample size would be 385 randomly selected inhabitants of Zagreb.

If just the quality of public transport (PT) is to be surveyed, the target population would be defined as the number of public transport service users in Zagreb. Based on the data from Zagreb Municipal Transit System, 816,438 rides are made daily by public transportation and each traveler makes two

rides per day on average. Using available information, we can determine the size of our target population as 408,219PT users. Based on previously defined values of E, r, and c and suggested formula for determining sample size, the sample should include 384 randomly selected PT users in Zagreb.

From this example, it is also evident that the sample size does not change much for populations higher than 20,000.

Execution

The survey should be conducted appropriately for the local culture. In our six cities we had better results conducting online surveys where participants were sure of their anonymity. We have sometimes resorted to a panel of interviewees to ensure good demographics representation and sufficient participation. The online process had the additional advantages of being cheap, easily reproducible for future assessments, and allows automatic collection and analysis of the responses.

The target group must be representative of the whole population in terms of random selection:

- Gender
- Age groups
- Education
- Etc.

A specific target group is selected for the indicator on accessibility for impaired groups.

Surveys should be collected in the months in which the averaged amount of traffic per day is in the range of +/- 2% of average daily traffic per year.

Surveys should not take place on holidays (e.g. Labor Day, Easter, etc.), other days when celebrations are organized, even when not holidays (e.g. Valentine's day, St Patrick's day, etc.), school holidays, the day after the change of summer and winter time, special events (e.g. regional festivals, sporting events, major concerts, etc.) or when extreme weather conditions occur.

Repeating the surveys in different years will depend on the consideration of the expected variation of the results (after implementation of some solution, external changes, etc.) versus the survey execution cost. However, cities that prefer to closely monitor the sustainability of urban mobility should repeat the surveys once a year with a randomly selected group of individuals. Target sample size can be modified if the size of the target population has changed since last surveying, but the values for the acceptable margin of error, confidence level and response distribution should be kept in order to ensure comparability of the results.

Survey questions

- Each survey should contain relevant demographic data and information for verification. For example:
 - What is your gender?
 - What is your age?

What is the highest level of education you have completed?
Which is your profession?
How many people live within your household?
Are there any children under the age of eighteen currently living in your household? If so, how many?
What is your marital status?

Other informative questions that can be relevant for some indicators are asking if the interviewee travels with a dependent person, if she/he has a PT pass, a driving license, a car, motorcycle or bike available. (driving license ...).

- A standard survey questionnaire is proposed in Appendix 3. The survey content must be adapted to the local culture. While in some cities it is appropriate to ask for the home address it can be subject to survey rejection for security reasons in others. Similarly, if there is a standard question on an option which is not available in the city (e.g. no park and ride) the related questions should be deleted. If one adapts the survey questions it should adapt the calculation spreadsheet as well. Open questions cannot be used for the indicator value calculation, but they can be valuable for a detailed qualitative analysis of the city situation or the consumer's expectations.
- Prior to conducting the survey, all relevant local regulations should be considered (e.g. regulations regarding privacy issues) and surveys adjusted accordingly.
- If executed with a poll taker, 10% of the polls executed by a single poll taker must be verified by contacting the interviewee. If fraud is detected, all polls executed by the poll taker should be considered invalid.
- All poll takers should be properly prepared for the poll taking and familiar with the survey content in order to be able to provide the required additional information to the interviewee or to give additional explanations regarding survey questions if needed. It is important to check the understanding of the different concepts used in the surveys (for example correct understanding of the difference car-pooling vs car-sharing).
- All poll takers should be equipped with all additional data needed (e.g. list of PT stops if there is a question that refers to the PT stops, etc.). Good preparation of poll takers is considered to be crucial to successful surveying.

c Traffic Modelling

For a part of indicators traffic models are proposed as methodology:

Emissions of greenhouse gases (GHG)
Energy efficiency
Air polluting emissions

The data for the three above-mentioned indicators are grouped in a third main category referred to further on as “calculation” methodology (M3).

The congestion and delays indicator is partly based on data representing distances travelled, which is to be obtained via traffic model calculation (or existing data bases, e.g. for public transport).



If cities do not have a traffic model calculation facility available, alternatives include referring to data obtained in earlier traffic model studies or, if also this data is also lacking, executing a survey (see above) to obtain the distances travelled with the different modes from a representative sample of transport (persons and freight as well) users.

For traffic modelling purposes, a number of free or commercial applications can be considered, some of them are (in alphabetical order):

Macroscopic

- Aimsun
- Cube Voyager
- DYNEV
- Emme
- OmniTRANS
- OREMS
- TransCAD
- TransModeler
- PTV Visum

Mesoscopic

- Aimsun
- Cube Avenue
- DTALite/NeXTA
- Dynameq
- DYNASMART
- DynusT
- OmniTRANS
- PTV VISSIM
- Tracks
- TRANSIMS
- TransModeler

The suggested methodology does not imply usage of any of the above-mentioned software but rather gives modelling guidelines for the purpose of uniform modelling procedures that can be used as a benchmark with other cities.

The application of mesoscopic (for small urban areas) and macroscopic traffic models is suggested. For this purpose, input data should include:

- aggregate measures of population;
- land use;
- origin-destination (OD) matrix;
- modal split;
- selection of routes between origins and destinations in transportation networks.

Model output values to be collected for indicator calculation are vehicle-kilometers.

Many models also directly generate emissions and energy consumption (for road traffic).

d GIS

GIS stands for geographic information system. A GIS for a city has to be produced via appropriate software packages. Many cities dispose of such a system in order to manage spatial (social and geographical) data.

Parameters based on spatial data are:

- Congestion and delays*
- Mobility space usage*
- Access to mobility services*
- Urban functional diversity*
- Opportunity for active mobility*

The data for the five above-mentioned indicators are grouped in a fourth main category referred to further on as “analysis” methodology (M4).

All indicators based on spatial data can be achieved by some simple GIS operations when the necessary data are available. When the data are not available, it needs to be collected by data capture (direct data input) or data transfer (input of data from other systems).

The two main types of data capture are:

Primary data sources:

Primary data sources are those collected in digital format specifically for use in a GIS project.

- Raster data capture: Remote sensing is a technique used to derive information about the properties of objects without direct physical contact. Today, the term is mainly used for Earth observation: the collection of data on the Earth’s surface by means of satellites, balloons, ships or other tools.
- Vector data capture: Two main branches are ground surveying and GPS

Secondary sources:

Secondary data sources are digital and analogue data sets that were originally captured for another purpose and need to be converted into a suitable digital format for use in a GIS project.

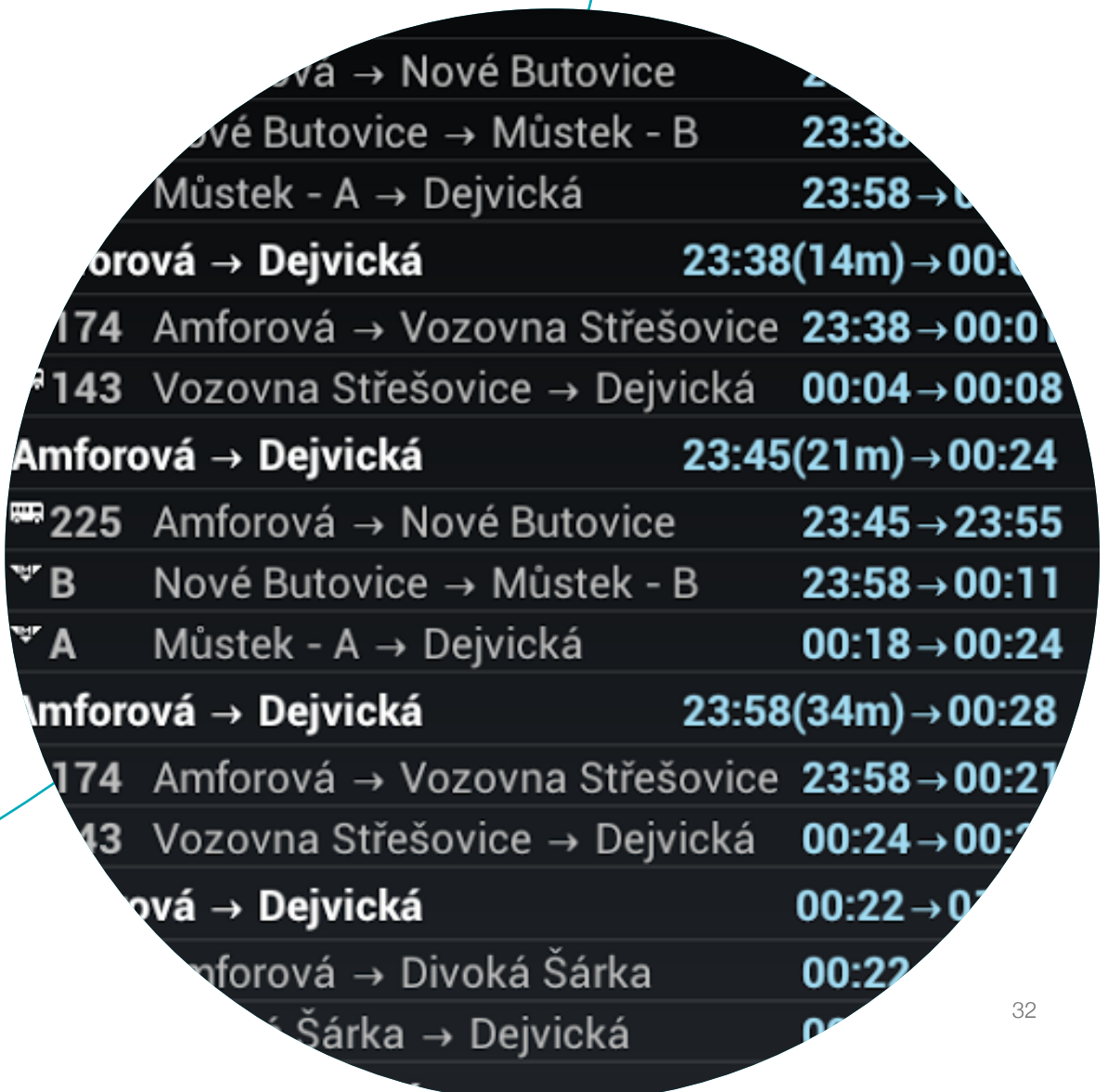
- Raster data capture: using scanners
- Vector data capture: digitizing vector objects from maps and other geographic data sources.

In this case, the main sources for data transfer are the existing databases that are discussed previously.

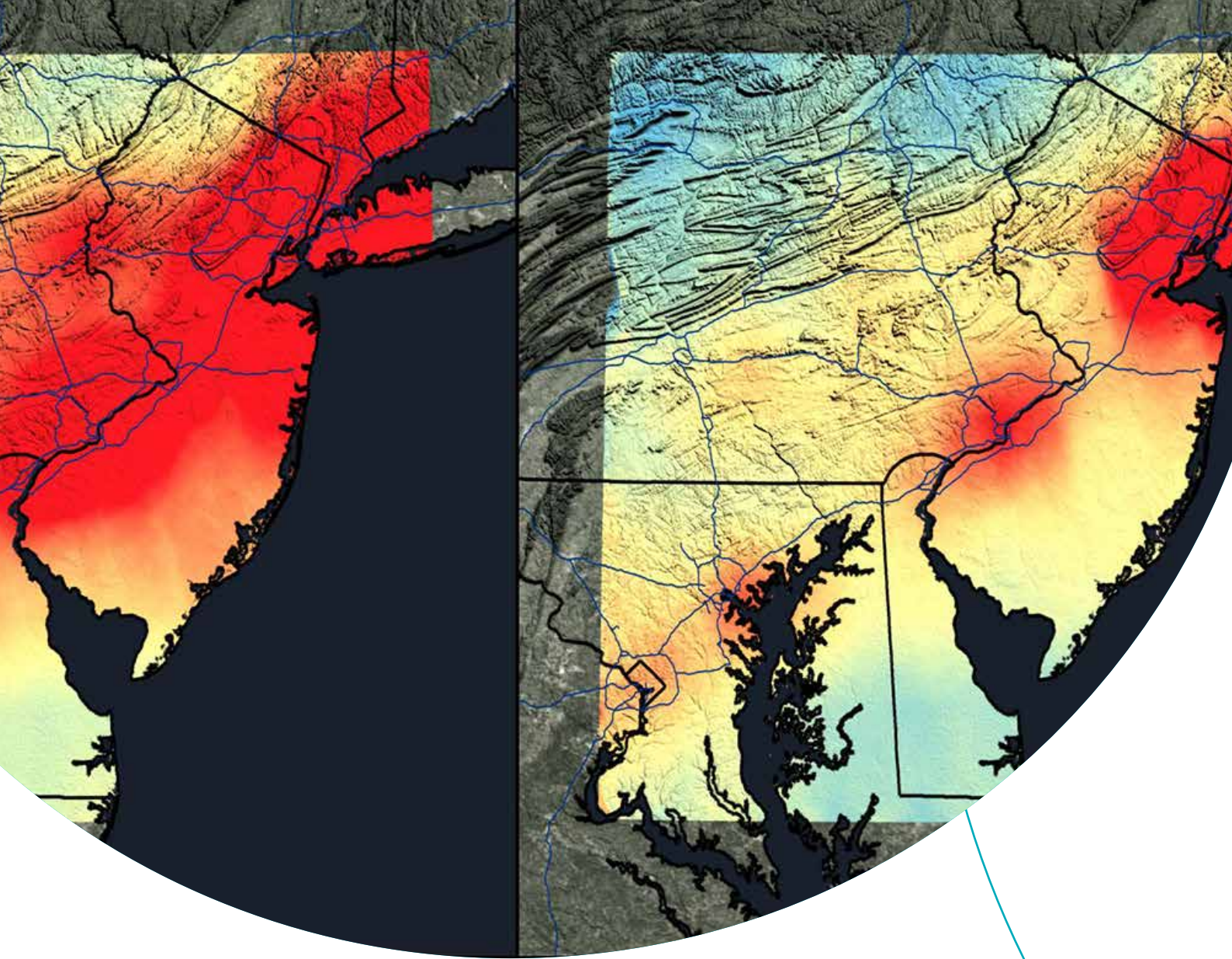
e Field measurement

Noise hindrance and congestion and delays indicators are grouped in a fifth main category referred to further on as “Measure” methodology (M5).

Specific methodologies are developed and described in the chapters that treat the indicators concerned in order to restrict the number of measurement points for these indicators to an acceptable level and to select the survey locations so as to represent typical problem areas (i.e. also areas where solutions should be targeted).



	ova → Nové Butovice	23:38
	Nové Butovice → Můstek - B	23:38
	Můstek - A → Dejvická	23:58 → 00:04
	Amforová → Dejvická	23:38(14m) → 00:04
174	Amforová → Vozovna Střešovice	23:38 → 00:04
143	Vozovna Střešovice → Dejvická	00:04 → 00:08
	Amforová → Dejvická	23:45(21m) → 00:24
225	Amforová → Nové Butovice	23:45 → 23:55
B	Nové Butovice → Můstek - B	23:58 → 00:11
A	Můstek - A → Dejvická	00:18 → 00:24
	Amforová → Dejvická	23:58(34m) → 00:28
174	Amforová → Vozovna Střešovice	23:58 → 00:21
143	Vozovna Střešovice → Dejvická	00:24 → 00:28
	Amforová → Dejvická	00:22 → 00:26
	Amforová → Divoká Šárka	00:22 → 00:26
	Divoká Šárka → Dejvická	00:22 → 00:26



VIII Methodology for the 19 WBCSD-SMP2.0 Indicators

Affordability of public transport for the poorest group

a Definition

Share of the public transport cost for fulfilling basic activities of the household budget for the poorest quartile of the population.

b Parameter

Affordability index of public transport for the poorest population quartile based on the relation between the cost for 60 relevant public transport trips and the average monthly household income.

c Methodology description

→ M1: Existing data (available in existing city or national database)

The parameter is based on existing socio-economic statistics or database analysis to identify the average household budget in the targeted specific group (the poorest 25th percentile of the population). In this context, affordability is defined as the fare expenditure made by a household as a percentage of its income. Therefore, affordability captures the ability of transportation system users to pay for transportation. A more affordable system is one that consumes a smaller share of users' incomes. The number of trips and the length of the trip are set for all cities at 60 trips of 10 km per month.

d Formula & Calculation method

$$AI = \frac{\sum_i TPT_i * F10km_i}{Minc_{25\%}} * 60$$

AI = Affordability Index of public transport for the poorest population quartile [% of household income]

TPT_i = Monthly percentage of PT trips with PT mode i [%]

F10km_i = Fare 10km PT trip with PT mode i [monetary unit]

Minc_{25%} = Average monthly income of poorest population quartile [monetary unit]

i = Available public transport mode [type]

60 = sixty trips per month

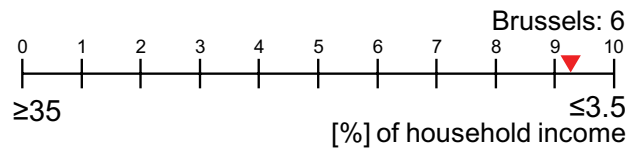
e Source

Methodology:

Inspired by the methodology used by the World Bank in Latin American cities Carruthers, R., M. Dick and A. Saurkar (2005), "Affordability of Public Transport in Developing Countries", Transport Papers, The World Bank Group:Washington.



f Scale



→ 0: A.I. >35%,

→ 10: A.I. <3,5%,

g Notes

It evaluates the ability to make necessary journeys to work or school, for health and other social services, and to make visits to other family members and friends or other urgent journeys, especially within the city, without having to curtail other essential activities.

- The definition suggests that the cost of transport has to be seen in relation to the household budget (to be extracted from socio-economic statistical databases).
- A fixed number of 60 necessary trips of 10km per month is assumed

h Additional guideline

If considered as an important topic the number of trips per month and the length of the trip can be adjusted by the cities to fit better the local context.



Accessibility for mobility impaired groups

a Definition

The accessibility for deficiency groups to transport and transport services.

b Parameter

Average reported convenience of city transport for target groups.

c Methodology description

→ M2: Survey

The outline of the “Survey methodology” is described in the general part. The target population is selected groups: 65+, people with (registered) visual disabilities or reduced mobility, pregnant women.

d Formula & Calculation method

The variable is the average survey score.

$$AccDGsc_{av} = \frac{\sum_i AccDGsc_i}{m}$$

$$AccDGsc_i = \frac{\sum_j AccDGsc_{ij}}{n_i}$$

Where:

AccDGsc_{av} = Averaged score of accessibility for deficiency groups of city transport. [%]

AccDGsc_i = Averaged score of deficiency group i. [%]

AccDGsc_{ij} = Averaged score of accessibility for deficiency group i by sub question j [%]

i = Deficiency group considered

n_i: Number of questions in survey related to deficiency group i [#]

m = Number of deficiency groups considered. [#]

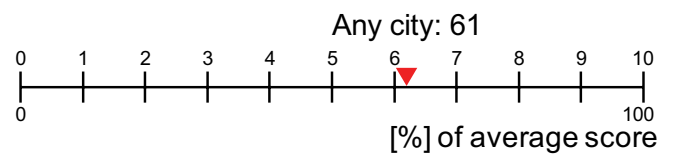
e Source

Methodology:

Wennberg, H., C. Hyden, A. Stahl (2010). “Barrier-free outdoor environments: Older peoples’ perceptions before and after implementation of legislative directives”. In: Transport policy, vol. 17; 464-474.

Survey on 27 usability factors, grouped in five categories: (1) physical barriers, (2) orientation and warning, relevant for blind and visually disabled, (3) bus stops and shops, (4) orderliness, (5) benches and chairs is described. Further detail included in the paper.

f Scale



→ Reported average satisfaction on a scale of 5 points

→ 0: 0 [%]

→ 10: 100 [%]

g Notes

- Elements of convenient accessibility for deficiency groups are, for example, the availability of special provisions for disabled people or elderly in public transport, provisions for blind people on walk ways and in railway stations, seats reserved for disabled people and the elderly in buses, reserved parking spaces for the disabled.



a Definition

Air polluting emissions of all passenger and freight city transport modes.

b Parameter

Total tailpipe harmful emission harm equivalent per year per capita.

c Methodology description

→ M3 (Traffic model) calculation

This indicator measures the total emission of air pollutants per capita, emitted by city transport. It is calculated by conversion of the total vehicle-kilometers per capita into a corresponding amount of pollutants. The total number of vehicle-kilometers is preferably collected by means of a traffic model.

The indicator is calculated with the existing parameters for energy intensity. A parameter measures how much energy is used to move both goods and people. The indicator represents the fuel used per unit of vehicle-

kilometers travelled by mode. Depending on the energy used per amount of fuel type (energy product), the most relevant harmful emissions endangering public health, i.e. NOx and PM10, are calculated. The emissions are expressed in NOx equivalent emission; this is calculated based on a NOx conversion factor per emission unit.

d Formula & Calculation method

The indicator is measured as the total tailpipe harmful emission equivalent per year per capita. It is calculated from the total amount of vehicle-kilometers per mode and per vehicle type in the following steps:

- **STEP 1:** converting vehicle kilometres into total emission of the different pollutants;
- **STEP 2:** converting the emissions of the different pollutants into one common value.

This is expressed in the following formula:

$$EHI = \frac{\sum_s Eeq_s * (\sum_{ij} A_{ij} * (\sum_{ck} S_{ijk} * E_{ijkcs} * I_k))}{Cap}$$

EHI = Emission harm equivalent index [kg NOx eq./cap per year]

Eeq_s = Emission substance type equivalent health impact value [factor]

E_{ijkcs} = emission of pollutant s per unit of energy consumed for fuel type k, emission class c of vehicle type j of transport mode i (g/l, g/kg)

A_{ij} = Activity volume (distance driven by transport mode i and vehicle type j) [million km per year]

S_{ijk} = Share of fuel type k per vehicle type j and per transport mode i [fraction]

I_k = Energy intensity per distance driven per fuel type k [l/km or kWh/km or kg/km]

Cap = Capita or number of inhabitants in the city [#]

k = Energy type (petrol, diesel, bio-fuel, electricity, hydrogen...) [type]

i = Vehicle type transport mode (passenger car, tram, bus, train, motorcycle, inland vessel, freight train, truck...) [type]

j = Vehicle class (if available specified by model (e.g. SUV,...) [type]

s = type of substance [type] limited to NOx and PM10

c = Emission class (euro norm) [type]

e Source

Data source: specific national values will be preferably used for the conversion factors in order to make calculations specific for the particular city. If no specific national values are available, values can be found in literature.

National values are expected to be available for the factors S_{ijk} , I_k and A_{ij} . In most cases S_{ijk} values are available per country. The differentiation between passenger cars, LDV, HDV and two wheels can be made using a central vehicle register. For the differentiation into vehicle technology classes, previously named extra information is required and should be available within the appropriate city services. For Belgium, the information about the vehicle fleet is available at

<http://mobilit.belgium.be/nl/publicaties/stat>.

E_{ijkcs} factors are for example provided by the EMEP/EEA in [EMEP/EEA Emission Inventory Guidebook2009, updated in 2012]. Here, emissions factors are listed per vehicle type (passenger car, LDV, HDV or two-wheels) and per vehicle technology and fuel type. Emissions expressed in g/vehicle-kilometer for pollutants among which: NOx, and PM10 are also available, e.g.: (<http://www.eea.europa.eu/themes/air/emep-eea-air-pollutant-emission-inventory-guidebook>).

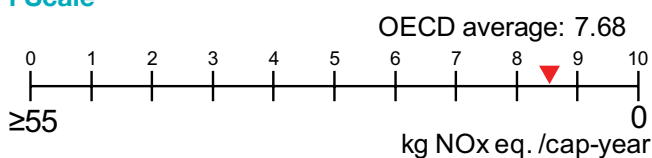
Factors Eeq_s are found, for example, in AEA

Technology Environment, 2005. "Damages per tonne emission of PM2.5, NH3, NOx and VOC's from each EU25 member state (excluding Cyprus) and surrounding areas":

Pollutant	Relative importance (based on 2007USD) with NOx, cost as reference
NO _x	1.00
PM ₁₀	1.06

(Source: AEA Technology (2005) and Wang, Santini & Warinner (1994), US cities as in Victoria Transport Policy Institute (2011), www.vtppi.org).

f Scale



→ 0: ≥55 [kg NOx eq./ cap-year]

→ 10: 0 [kg NOx eq./ cap-year]

g Notes

- In contrast to the climate change issue where relative impact of all GHG can be compared thanks to CO2 equivalents, here health values are used as a starting point to calculate the mutual weight of the pollutants in terms of their impact on air quality. It is understood that the marginal health impact is different depending on the base levels in the city. For reference reasons one fixed health factor is used per added unit.
- The indicator is focused on the most relevant harmful emissions endangering public health: NOx and PM10. PM2.5 emissions are also an important threat for public health. They are not part of this indicator as PM2.5 emissions data are not universally available and SMP2.0 methodologies have been built to be as attainable as possible. Other harmful pollutants (CO,HC, SOx) are also not considered in the parameter calculation, both to keep the methodology simple and because there is a lack of adequate theoretical values for health impact (some studies give an indication that the impact of the additional emissions are dependent on the existing pollution levels).
- The emissions volumes are calculated per vehicle type and not measured by air pollution in the city which includes stationary emissions. The indicator is to have a fair estimate of the emissions linked to mobility only.
- The emissions per distance driven condition is added in order to validate the effect of measures

reducing the emission of the vehicle park and the smoothing of traffic flow.

There is much ongoing research about comprehensive air pollution indices or air quality indices (API's respectively AQI's). Several countries provide such an AQI, but there is not a unique and internationally accepted methodology set for the composition of the indicator. Sometimes the costs of the separate pollutants in is expressed in DALYs (disability-adjusted life years) by combining pollutant emissions and their health risks caused (lost years of life and lost healthy years) (Ruggieri & Plaia, 2011). But DALYs could differ highly between different countries, because of the varying health background and the level of development, so calculations would be difficult to compare between cities in highly different economic regions. If a traffic model is not available, a statistically reliable survey has to be conducted with population, commuters and visitors regarding passenger travel and also with companies regarding freight (M2: Survey).

h Additional guideline

Alternative methods for estimating the vehicle-kilometers driven are field measurements (traffic counts on representative locations) or surveys (enquiring people's trip behavior). Of course, if the vehicle-kilometers are available in existing city databases on mobility, they can be used too.

The guidelines for alternative approach related to GHG emission and to energy efficiency can be used to estimate the values for this indicator. The age of the car park (national data can be used if this is considered realistic for the local situation) can be used to select the (single) emission norm if no other data allow to be more precise.

Emission standard data (with the year of implementation) can be found amongst others at <http://transportpolicy.net/> http://delphi.com/manufacturers/auto/powertrain/emissions_standards/ https://en.wikipedia.org/wiki/European_emission_standards (content of this website might not be stable)



If the city can't provide the data relative to the distance driven or vehicle park, the fuel consumption for transport can be estimated based on the fuel taken from the local fueling stations. Distance relation to fuel consumption estimated can be found at

- <http://www.co2count.org.uk/defradoc.pdf>
- http://www.ukconversionfactorscarbonsmart.co.uk/documents/2014%20Emission%20Factor%20Methodology%20Paper_FINAL-4Jul14.pdf

<http://www.ghgprotocol.org/files/ghgp/tools/co2-mobile.pdf>

For public transport the companies can report on the fuel or electricity used to power their vehicles.

Noise hindrance

a Definition

Hindrance of population by noise generated through city transport.

b Parameter

Percentage of population hindered by city transport noise based on hindrance factors for noise level Lden measurements.

c Methodology

→ M5: Field measurement

The indicator is evaluated based on field measurement at locations near a representative random selection of houses of city inhabitants. Standard values are used to consider the level of hindrance perceived by the inhabitants.

The difficulty to measure traffic noise in a city is that:

- ideally a large number of noise measurements is needed,
- the measurements should cover a sufficiently long period (ideally at least 24 hours),
- Noise is often a result of many activities but here only the impact of traffic noise should be included.

In order to restrict the amount of measurements to an acceptable level, the methodology proposed is based on a set of 50 measuring points, located in different types of living environments in the city:

- o 5 Locations near highways
- o 5 Locations near ring road
- o 10 Locations near access road to the city centre
- o 10 locations within typical living neighbourhoods
- o 10 locations near sensitive functions (schools, hospitals, elderly)
- o 5 locations in quarters with low income residents
- o 5 locations in recreation zones (sporting area, parks, etc.)

- During the measurements, other sources of noise that might be disturbing the measurements are noted (e.g. person mowing the lawn, ...). This allows checking and correcting of possible disturbances afterward.
- As this previous issue requires the permanent presence of a surveyor at the noise measurement location, long-term measurements are not attainable. The minimal duration is determined by the least loaded roads (minimal number of cars needed in order to have a representative number of noise events) and by the possibility to filter out occasional events from the total measurement period. The measurements should be executed during the daytime period (traffic noise is more important during the daytime, higher risk of other noise sources in night time).
- The measurements are weighted depending on the density of the population in the area concerned. In the methodology proposed, 12 density classes MWF_i (range of the classes depending on the density range in the city) have to be defined. The proposed distribution of the classes is the following:

MWF(i) VALUE BASED ON DENSITIES IN DISTRICT MEASUREMENT LOCATION		
MWF(i)	DWELLINGS/ha	LARGE ATTRACTION POLES, SCHOOLS OR ENTERPRISES
1	≤ 15	NO
2	≤ 15	YES
3	> 15 ≤ 25	NO
4	> 15 ≤ 25	YES
5	> 25 ≤ 40	NO
6	> 25 ≤ 40	YES
7	> 40 ≤ 55	NO
8	> 40 ≤ 55	YES
9	> 55 ≤ 75	NO
10	> 55 ≤ 75	YES
11	> 75	NO
12	> 75	YES

Noise measurements:

- Upon arrival at a measurement location, the measurement is always conducted, whatever the circumstances. Disturbance by non-traffic-related noise sources is filtered out afterwards.
 - It is proposed to execute the measurements 1 meter from the facade, at a height of 1.5 meters, in order to represent as close as possible the noise hindrance inside the houses and other buildings. If not possible (garden not accessible, no cooperation from owner, etc.) the measurement takes place closer to the road (to be noted as a disturbing element). In case of apartment buildings, the standard approach is to have measurements done at ground level (metering position at 1.5 meters high), according to the general convention in the EU. Otherwise the measurement takes place at a location that is the most similar nearby. If there are good reasons to apply another approach (e.g. measurement at another height), other measurement locations can be used too.
- Not applying the standard, however, makes comparing results more difficult (between different measurements periods, different areas in the city, etc.).
- During the survey, some parameters need to be registered:
 - o Traffic flow: number of vehicles per 10 minutes
 - o Other sources of noise (trains, airplanes, etc.)
 - o Road characteristics (distant to the roadside, type of road surface, speed limit, road type, number of lanes, presence and type of junctions, etc.)
 - o Characteristics of the area: type of buildings, proofs of recent changes, presence of green...
 - o Weather conditions (sun, cloudiness, wind, rain...)



Figure 9: Examples of traffic noise measurement locations

Calculation OF L_{den} :

L_{den} is defined in terms of the “average” levels during

$$L_{den} = 10 \lg \left[\left(\frac{12}{24} \right) \cdot 10^{\frac{LD}{10}} + \left(\frac{4}{24} \right) \cdot 10^{(LE+5)/10} + \left(\frac{8}{24} \right) \cdot 10^{(LN+10)/10} \right]$$

Here LD, LE, and LN are the A-weighted long term LAeq as defined in ISO 1996-2 (1987) for the day (7-19h), evening (19-23h), and night (23-7h) determined over the year at the most exposed facade. The time periods can be adapted by the cities if local culture or

habits differ from the proposed partition of day period (also in accordance to the newer ISO editions on this issue).

d Formula & Calculation method

$$NI = \frac{\sum_i (MWF_i * HFL_{den,i})}{\sum_i (MWF_i)}$$

$$L_{den} = 10 \lg \left[\left(\frac{12}{24} \right) \cdot 10^{\frac{LD}{10}} + \left(\frac{4}{24} \right) \cdot 10^{(LE+5)/10} + \left(\frac{8}{24} \right) \cdot 10^{(LN+10)/10} \right]$$

NI = Noise hindrance index[% of population]

i = Measurement number[#]

MWFi = Measurement weight factor i (depending on population density of the area, considering twelve density classes) [#]

HFLdeni = Hindrance factor (part population) at Ldeni with HFLdeni value in table:[dB(A)]

LD= Noise daily factor (7-19h) or day time value relevant for region [dB(A)]

LE= Noise evening factor (19-23h) or evening time value relevant for region [dB(A)]

LN=Noise night factor (23-7h) or night time value relevant for region [dB(A)]

Some sample hindrance factors for respective Lden values

1	if Lden > 84 dB(A)
0,9	if Lden > 81 dB(A)
0,8	if Lden > 78 dB(A)
0,7	if Lden > 75 dB(A)
0,6	if Lden > 71 dB(A)
0,5	if Lden > 67 dB(A)
0,4	if Lden > 62 dB(A)
0,3	if Lden > 57 dB(A)
0,2	if Lden > 49 dB(A)
0,1	if Lden > 37 dB(A)
0	if Lden < 37 dB(A)

e Source

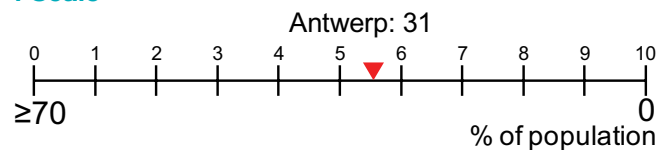
Methodology:

EU Noise directive during the period 2005-2010

Source H.M.E. Miedema, and H. Vos, (1998),

“Exposure-response relationships for transportation noise,” J. Acoust. Soc. Am. 104(6), 3432-3445.
Relevance see: S. McGuire, P. Davies, (2008), An overview of methods to quantify annoyance due to noise with application to tire-road noise

f Scale



→ 0: ≥70 [% of population]

→ 10: 0 [% of population]

g Notes

- Traffic noise by city transport including road and rail transport for passenger and freight.
- The measurements are weighted depending on the density of the population in the area to get a good representation of the noise hindrance perceived. This additionally allows for identification of priority locations where to focus noise abatement measures.
- Research has shown that it is possible to use standard values to estimate the annoyance levels based on noise levels.

h Additional guideline

If the city has a noise model of the area these results can be used to identify L_d , L_e and L_n or directly L_{den} on the selected spots.
In order to avoid choosing reference places intentionally it is recommended to choose the places prior to run the noise model.

Fatalities

a Definition

Fatalities by road and rail transport accidents in the city.

b Parameter

Number of deaths within 30 days after the traffic accident as a corollary of the event per annum caused by urban transport per 100,000 inhabitants.

c Methodology description

→ M1: Raw data from city or national databases
Indicator is based on the existing databases, mainly Statistics of Road Traffic Accidents. Reported data should be in the form of annual transportation fatalities per 100,000 people. This adjustment is needed for the purpose of comparability of data among different cities or with national averages and target values.

d Formula & calculation method

$$FR = \frac{\sum_i K_i * 100000}{Cap}$$

FR = Fatality rate [# per 100.000 population per year]

Ki = Number of persons killed in transport mode i [# per year]

Cap = Capita or number of inhabitants in the city [#]

i = Transport mode (passenger car, freight traffic, tram, bus, train, motorcycle, river transport, etc.) [type]

e Source

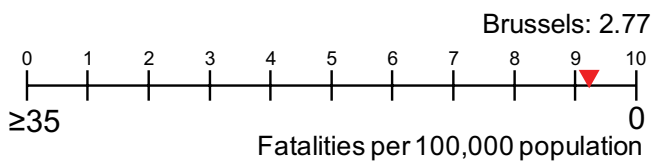
Methodology:

Global Cities Institute (2013), Global City Indicators, "Profile Indicators", p. 2; <http://www.cityindicators.org/Default.aspx>.

- The international definition of Fatalities, has been adopted by the Vienna Convention in 1968, as "A human casualty who dies within 30 days after the collision due to injuries received in the crash."

Data sources: National/regional or city data sources or World Bank/UN Global Indicators databases. (Referring only road casualties, in the proposed WBCSDSMP2.0 methodology rail casualties have to be added.)

f Scale



- 0: 35 [fatalities/100.000 capita]
- 10: 0 [fatalities/100.000 capita]
- Reference for scale 0; "Vision zero" objective
- Reference for scale 10; Egypt, 2000: 42 fatalities per 100.000 pop.

g Notes

- Although the OECD, for example, has launched clear definitions of types of injuries, it is concluded that is not possible to identify reliable and comparable figures of injuries due to underreporting of transport injuries and too divergent local definitions (even for well performing countries for traffic safety). Therefore, the advice is to limit the indicator to fatalities.
- "Non-fatal crash injuries are poorly documented. For every road traffic fatality, at least 20 people sustain non-fatal injuries. The severity of injuries sustained ranges from those that can be treated immediately and for which medical care is not needed or sought, to those that result in a permanent disability. Reliably assessing injury severity requires clinical experience; police in many countries who record official information on injuries often do not have sufficient training to reliably categorize injuries. Different definitions of injury severity further complicate reporting of injuries." (WHO (2013), Global Status Report on Road Safety, p. 7).

h Additional guideline

Several of our 6 cities were surprised by their high score on Fatalities. It is because the scale is representing the extremes observed worldwide. As such most developed cities might get a value above 9.

Access to mobility services

a Definition

Share of population with appropriate access to mobility services.

b Parameter

Percentage of population living within walking distance of public transport (stop or station) or shared mobility (car or bike) system.

c Methodology description

→ M4: Analysis (spatial data) (using GIS)

The proposed parameter analyses accessibility to mobility services in terms of "the percentage of population living within a public transport service area in a metropolitan area". This is the percentage of people living within a straight-line distance of 400 meters from a public transport stop (including paratransit such as minibuses) or 800 meters from a rail transport stop. In addition to radial straight-line distance measurements, the real distance measured along the street network can be used too (this is of course more realistic). Values to define the service area based on real distances to be used are 500 meters for bus stops and 1,000 meters for rail stations. If circles based on straight-line distances are used as catchment areas, barriers such as rivers, dams, highways, etc. must be included in order to exclude the areas that are not reachable directly from the public transport stop.

The percentage of people living within the service areas can be calculated by using spatial data – GIS using the Buffer Wizard (e.g. with software ArcGis and ArcView). The Buffer Wizard allows rings to be drawn around features (points, lines or polygons) at a specified distance from that feature. To use the Buffer Wizard, the map must have defined units; otherwise the buffers cannot be processed. The necessary data are two different shape files, one with public transport stops and one with the population.

d Formula & Calculation method

$$AccI = \frac{\sum_i(PR_i)}{Cap}$$

AccI = Appropriate access Index [% of population]

PR_i = Number of people living within acceptable radius of a station (or stop) of public or shared mode i (800 m for train, metro or car sharing station, 400m for bus or tram stop or bike sharing station not yet counted in another mode range [#]

Cap = Capita or number of inhabitants in the city [#]

By using GIS, it is possible to calculate the percentage of people living within a public transport service area (400 meters from a public transport stop or 800 meters from a rail transport stop). Using the Buffer Wizard with a radius of 400 meters and one of 800 meters on the shape file of the public transport stops, overlap can be calculated with the people who live in this radius. With GIS of the street and public services networks, it is highly recommended to use real walking distance along the street networks. In this case, 500 and 1,000 meters should be used, factoring in physical barriers.

Depending on the specific climate or other local circumstances, city-specific catchment areas can be adopted (e.g. in the Middle East).

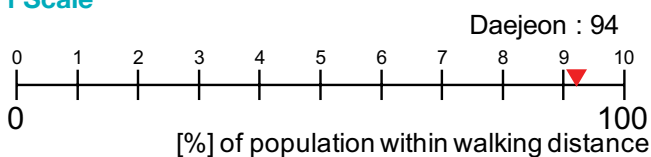
e Source

Methodology:

The proposed limit of 400 meters and 800 meters is based on:

- TNO Business Unit Mobility and Logistics (2007), Refinement and test of sustainability and tools with regard to European Transport policies, p.110. "The commonly accepted radius is 400 metres, which has been found to be the maximum distance that a person is likely to walk to use public transport services."
- Transport for London (2010), Measuring Public Transport Accessibility Levels, p.2;<https://s3-eu-west-1.amazonaws.com/londondatastore-upload/PTAL-methodology.pdf>. "For buses the maximum walk time is defined as 8 minutes or a distance of 640metres. For rail, underground and light rail services the maximum walking time is defined as being 12minutes or a walking distance of 960 metres."
- Center for Transportation Research – University of Texas (2005), Measuring Access to Public Transportation Services: Review of Customer-Oriented Transit Performance Measures and Methods of Transit Submarket Identification, p. 13;http://www.utexas.edu/research/ctr/pdf_reports/0_5178_1.pdf "A common practice in transit planning is to assume that people are served by transit if they are within 0.25 mi (or 400 m) of either a transit route or stop (Murray 2001, Peng et al. 1997, Ramirez and Seneviratne 1996). However, a study conducted by Alshalalfah et al. (2005) suggests that the 0.25 mi criterion underestimates how far people are willing to walk to access transit."

f Scale



- ➔ 0: 0 [% population]
- ➔ 10: 100 [% population]

g Notes

- Access to urban infrastructure is obvious for car and motorcycle owners. Problems arise for people who have no motor vehicle available and who are designated for public transport for trips over longer distances in urban area. Biking could also be regarded as a complementary basic transport means if distances are not too far. Because of the relevance of the distance threshold for metropolitan cities, the indicator only accounts for public transport accessibility levels.
- A distance of 400 meters for bus and tram stops and of 800 meters for metro and train stops is assumed to be acceptable walking distances.
- Distances of 400 meters for shared bike stations and 800 meters for shared car systems are also to be considered as acceptable for mobility services.

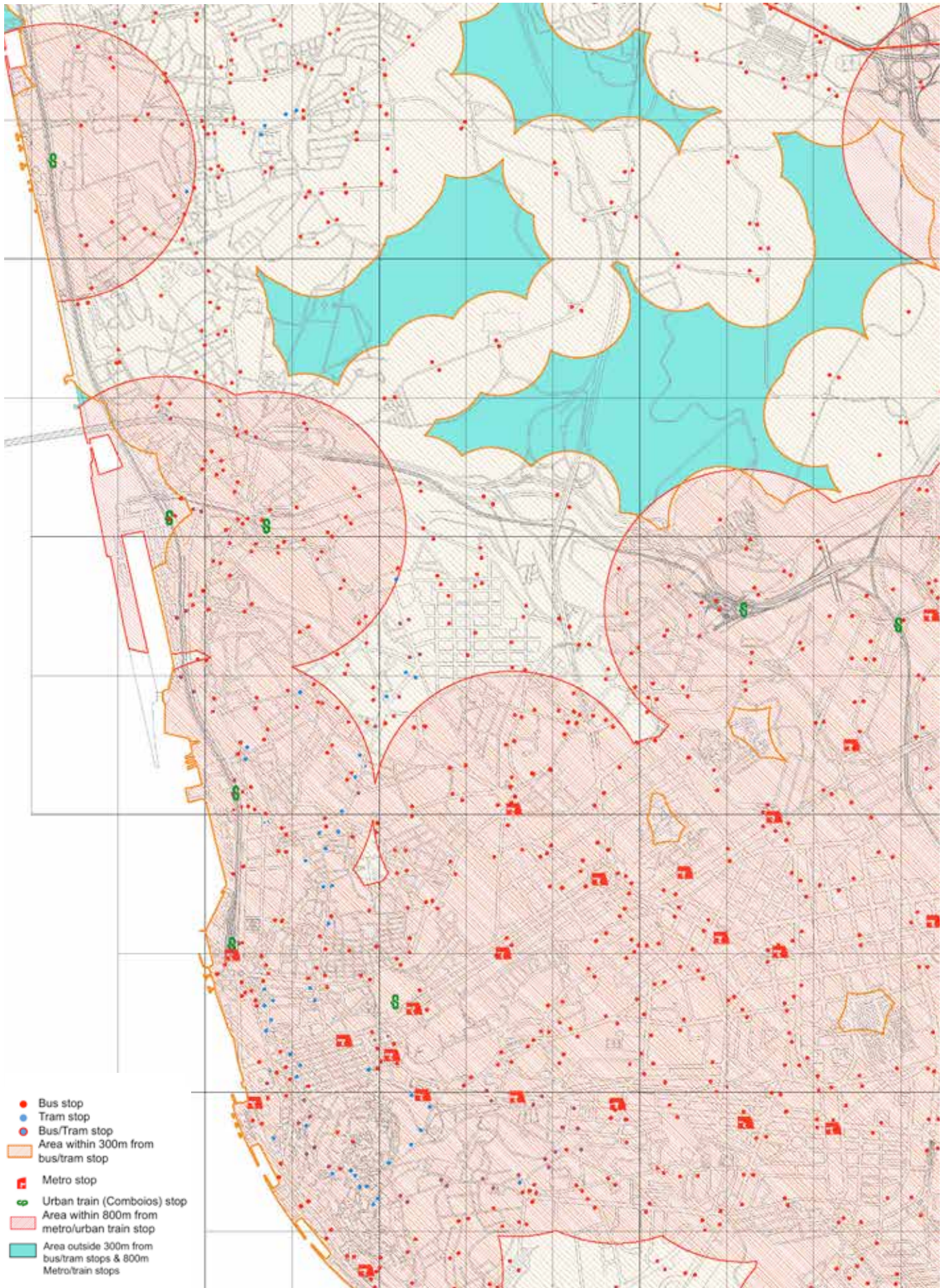
h Additional guideline

The following approaches can be used to calculate this indicator.

- 1) Use a Geographic Information System (GIS) to draw a circle around each bus and tram stop and train and metro stop. Within the circle of 400 m radius for buses and trams or 800 m radius for train / metro, determine the percentage of population. Enter the percentage of population within the total area covered by these circles into the spreadsheet for "Access". This will generate the Indicator "Access". Note that some online map providers offer an easy to use GIS (e.g. <http://gmapgis.com/> for google-maps)
- 2) An alternative approach is to use a 400 m by 400 m grid applied to the city. Within each grid determine the percentage of the total population. Population is given in the most recent City census and may be divided by Ward, Borough, Zone, or other appropriate division. Within each grid identify if there is at least one public transportation stop (bus, metro, train). Enter the data for each grid into the spreadsheet for Indicator "Access".
- 3) A drawing received from the City with the identification of the areas covered by buses, tram, etc. (400m to a stop) and the areas covered by metro, trains and boats (800 m to a station) can also be used.
- 4) One can also start the calculation from the number of people not living within walking distance. In many cities these areas not covered by public transport will be less extensive.



Figure 10 : Detail of the map built in Lisbon to calculate the Access to mobility services. The entire map covers the metropolitan area of Lisbon.



Quality of public area

a Definition

Presence in the city of attractive areas such as pedestrian street or squares which facilitate social activities and encourage citizens' interaction.

b Parameter

Reported social usage of streets and squares and subjective appreciation of the public area quality

c Methodology description

→ M2: Survey

The outline of the "Survey methodology" is described in the general part. A proposal for a survey form is available for cities. The target population is the users and non-users of public spaces.

- Questions refer to usage and perceived quality of public places in both the living neighborhoods as in the city center.

d Formula & Calculation method

The variable is the average survey score.

$$PAsc_{av} = \frac{\sum PAsc_i}{m}$$

$$PAsc_i = \frac{\sum_j PAsc_{ij}}{n_i}$$

$PAsc_{av}$ = Averaged score of public area quality appreciation and sociability

$PAsc_i$ = Averaged score for public area quality appreciation and sociability for surveyed aspect i

$PAsc_j$ = Averaged score for public area quality by sub-question j for aspect i

i = aspect of public area surveyed

m: number of aspects surveyed

n_i: number of sub-questions for aspect i

e Source

Methodology:

Matan, Anne and Peter Newman (2012), "Jan Gehl

and new visions for walkable Australian cities", World Transport Policy and Practice volume 17.

The described methodology is also adopted by the Victoria Transport Policy Institute in its tool for evaluating The Quality of Transport Services and Facilities and European Urban Audit (2013) complement on "Quality of life in cities" based on a perception survey in 79 European cities.

f Scale



→ Scaling: Reported average usage and satisfaction concerning public spaces on a scale of 0 to 100%, based on individual scores on the different questions.

→ 0%: 0 [%]

→ 100%: score 10

→ 10: 100 [%]

g Notes

- Successful public spaces have four key qualities: being accessible, safe, green and comfortable. They are easily accessible women with pushchairs, for elderly and impaired people and safe for children. The space is green and comfortable, providing activity infrastructures and seating structures. It is a sociable place where people meet each other and take other people when they come to visit.
- Accessibility and comfort are already covered by other indicators; in order to avoid redundancy, this indicator is limited to sociability (measured via the intensity of usage of the public spaces: for city center as well as neighborhood) and the good image (measured via the perceived quality by the city population for city center as well as neighborhood).
- As the public area has two main functions – "link" (i.e. for traffic) and "place" (i.e. to spend time) – this indicator has to measure to what degree the place's function is hindered or pushed away by traffic.

a Definition

Functional diversity refers to a mix of spatial functions in an area, creating proximity of mutual interrelated activities.

b Parameter

Average presence (value 1) or not (value 0) of out of 10 spatial functions related to daily activities except for work in grids of 1 km x 1 km.

c Methodology description

→ M4: (Spatial) analysis

The first step in the methodology is the division of the city area into squares of 1 km x 1 km by using existing data and GIS. The next step is to identify what functions are present in each grid, and what functions are not. Functions are defined by 10 land-use categories (see list below). Accordingly, maps can be created also by using GIS. The score of presence of the 10 functions is weighted with the population fraction (related to the city population) in the grid concerned.

The predefined functions are listed below:

- 1 Business (industry, offices, logistics, etc.)
- 2 Energy resources (e.g. petrol and gas stations)
- 3 Hospital and medical services
- 4 General services (post, administration, etc.)
- 5 Schools
- 6 Commercial (shops, supermarkets)
- 7 Sports and recreation
- 8 Residential (families)
- 9 Residence for elderly people
- 10 Parks and greens

d Formula & Calculation method

The territory of the city is divided in grids of 1km X 1km. The presence of 10 functions (listed above) is indicated in each of the grids and weighted with the population living in the area.

$$FDS = \sum_{ij} Pop_i (\forall Pres_{ij} > 0)$$

Where:

FDS = Functional diversity score[%]

Pop_i = Fraction of population in the city in zone i [fraction]

Pres_{ij} = Presence of functions j in zone i (it is equal to 1 if there is a presence; it is equal to 0 if there is not a presence) [binary]

e Source

Methodology:

The methodology is a simplified variant of the Shannon Index. The description and use of the spatial entropy methodology can be found in the following sources:

- Batty, M. (2010), "Cost, Accessibility, and Weighted Entropy", Geographical Analysis vol. 15, issue 3, pages 256–267, 1983.
- Boussauw, K. (2012), Aspects of spatial proximity and sustainable travel behaviour in Flanders, Ghent University, Faculty of Sciences.
- Brandmüller, T. (2011), "Land cover and land use", Eurostat regional yearbook 2011, pages. 166-167, 2011.

f Scale



- Scaling: The average of the scores for all the grids in the city, expressed as a percentage.
- 0: average score 0 [%]
- 10: average score 100 [%]

g Notes

- This indicator is complementary to the commuting travel time indicator. Additionally it also measures the proximity from the home of other functions than work places, such as schools, services, shops.
- The proximity is measured in such a way that the opportunities for walking from home to these daily activity destinations is indicated, that is the reason grids of 1 km x 1 km are proposed. If a more "organic" limitation of, for example, neighborhoods, is more appropriate (e.g. because spatial data on these neighborhoods are more easily available), the city can choose an alternative spatial unit instead of the 1 km x 1 km grid. However, the more the average surface of these alternative units differs from 1 km², the less the indicator value represents opportunities for walking and the less the indicator value is comparable with the indicator values of other cities.
- Cities can choose other spatial functional categories than the 10 presented in the standard methodology as far as they are in relation with daily mobility needs.

Commuting travel time

a Definition

Duration of commute to and from work or an educational establishment.

b Parameter

Average duration of the combined outward journey and return journey to work or an educational establishment expressed in minutes per person per day.

c Methodology description

M2 = Survey

The outline of the "Survey methodology" is described in the general part. The target population is the inhabitants commuting to work or for education purposes.

d Formula & Calculation method

The valuable is the average survey score.

$$Tcom_{av} = \frac{\sum Tcom_i}{n}$$

$$Tcom_i = Tout_i + Treturn_i$$

Where:

Tcom_{av} = Average commuting time[minutes/day]

Tcom_i = Averaged commuting time surveyed person i

Tout_i = Commuting time home to work/school [minutes/day]

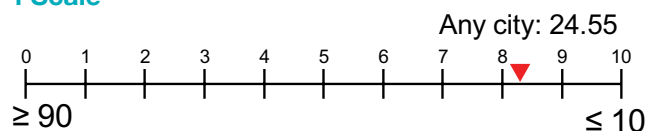
Treturn_i = Commuting time to home by person i [minutes/day]

n = Number of persons in survey

e Source

Methodology: The Gallup Organisation, Hungary (2009), Perception survey on quality of life in European cities.

f Scale



→ 10: ≤ 10 [minutes per day]

→ 0: ≥ 90 [minutes per day]

g Notes

The methodology concentrates on a certain trips to work/education because they are the most important and inflexible trips for people and this allows a clear definition for the interviewees. Besides, commute for other types of activities is represented in Functional Diversity.

Economic opportunity

a Definition

Degree of accessibility to the job market and education system.

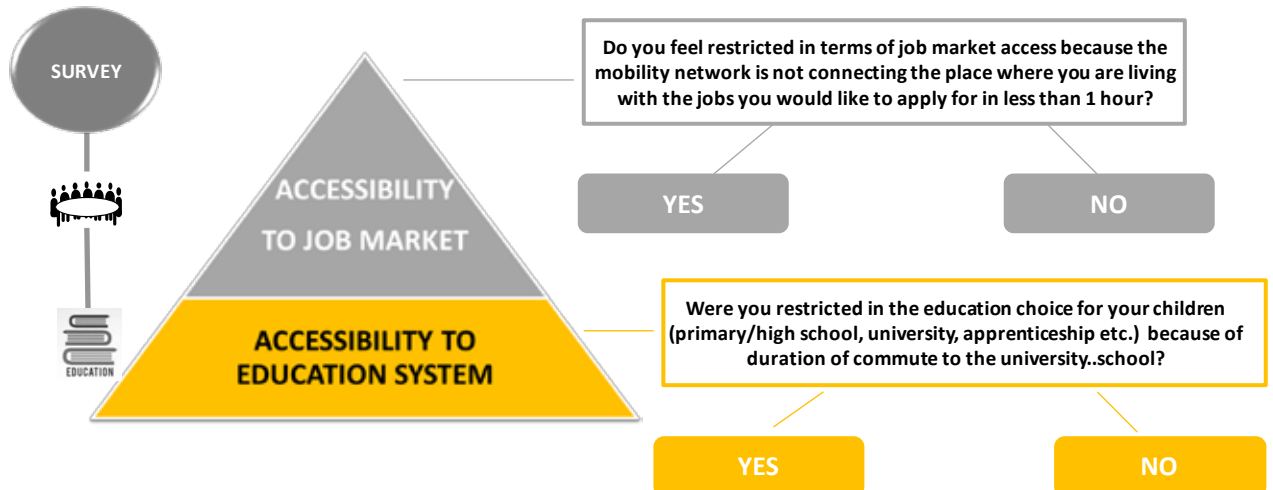
b Parameter

Citizens' perception of potential difficulties in accessing the job market and/or education system due to mobility network.

Methodology description

M2 = Survey

- At least half of the interviews have to be addressed to inhabitants of the city. A reasonable distribution between the different types of transport modes has to be obtained.



d Formula & Calculation method

The valuable is the average survey score

$$EOsc_{av} = \frac{EOjob_{av} + EOedu_{av}}{2}$$

$$EOjob_{av} = \frac{\sum EOjob_i}{n}$$

$$EOedu_{av} = \frac{\sum EOedu_i}{m}$$

Where:

EOscav = Averaged score of restriction of economic opportunity.

EOjobav = Averaged score of restriction to job market [%]

EOeduav = Averaged score of restriction to education market [%]

EOjobi = Number of answers of “No” in the survey of job

EOedui = Number of answers of “No” in the survey of education

n = Numbers of people for job survey

m = Numbers of people for education survey

e Source

2015 WBCSD SMP2.0 indicators work stream study.

f Scale



→ 0: 100[%]

→ 10: 0 [%]

g Notes

- The indicator is set to gauge the contribution of transportation system in terms of citizens’ accessibility to their basic social and economic needs;
- Attractiveness for new businesses was not included as it would be too subjective (from a citizen perspective). Such topic should be discussed with a panel of experts/city representatives.
- Accessibility to healthcare system was not included as it seems less related to the mobility network and more with urban planning.

h Additional guideline

- Information stemming from commuting travel time indicator should also be taken into account -in a qualitative formto further investigate what would be the maximum travel time deemed acceptable (i.e. not felt constrained), as well as to double-check consistency in the questionnaire.
- Should a municipality be particularly keen in tackling the economic opportunity theme, especially from a strictly economic point of view, it should try to retrieve hard data related to the gross value added (GVA) by the city transport sector per capita (only working people).

Net public finance

a Definition

Net results of government and other public authorities' revenues and expenditures related to city transport.

b Parameter

Net government and other public authorities' revenues from transport-related taxes and charges minus operational and other costs per GDP; investments are excluded from the parameter calculation.

c Methodology description

→ M1: Raw data (existing databases)

The net public finance related to city transport are the incomes minus running costs, which should be collected from existing databases.

d Formula & calculation method

$$NPF_i = \frac{\sum_i C_i - \sum_j O_j}{GDP}$$

NPF_i = Net Public Finance indicator of the city transport [%]

C_i = City government annual revenues from transport related Charges (all modes) [currency/year]

O_j = City government annual operational costs related to city transport (all modes) [currency per year]

GDP = Gross Domestic Product of the city (or the region considered) [currency per year]

e Source

Methodology:

LITMAN, T (2013), Economic Development Impacts, Evaluating Impacts On Productivity, Employment, Business Activity and Wealth, Victoria.

f Scale



→ 0: ≤ (-2,5) [% of GDP]

→ 10: ≥ 0 [% of GDP]

g Notes

– This indicator reflects the affordability for governments to sustain the expenditures in the transport system.

– Costs are limited to OPEX (OPerationalEXpenditure);

CAPEX (CApitalEXpenditure) is not considered.

- The indicator should cover the total transport systems operational costs and not only focus on public transport operation. Costs of all modes (rail and road, inland waterways and persons as well as freight) inclusive of infrastructure maintenance costs should be considered.

h Additional guideline

Some guidance on what should or should not be included for calculation:

Revenues to be considered

- o User contributions to the use of public transport
- o Parking fees (public parking area)
- o Retributions for valuable waste
- o City taxes from Taxi services, toll road, city entry permits, use of infrastructure, ownership of a transport equipment

Revenues NOT to be considered

- o Sales of replaced equipment
- o Received subsidies from any authority
- o Collected common fines
- o Gifts by third party not related to transport services offered / to be offered

Costs to be considered

- o Manpower cost directly assignable to public transport (drivers, rolling equipment maintenance personnel...)
- o Energy sources
- o Rental / leasing
- o Insurance premium
- o Repair and maintenance cost (materials and workers not on pay-roll) of roads, public transport network etc.)
- o Public Relations (public transport / parking.)
- o Maintenance of streets under city responsibility

Costs NOT to be considered

- o Purchase
- o Other manpower cost
- o Paid fines
- o Taxes
- o Retributions to authorities
- o Payback of rent and capital
- o Sponsorships
- o Insurance premium for workers (must be included in manpower cost)
- o Research costs

This list is for reference only, it is not exhaustive.

It is to be noted that the interpretation of the score should consider which were the elements included in the calculations. Indeed some modes or services are more “costly” than others and the score will tend to seem good compared to the proposed scale if

those are not included (e.g. road maintenance, bridge maintenance etc.). Similarly the indicator result might seem too low if revenues such as parking fees are not included in the sum.

Mobility space usage

a Definition

Proportion of land use, taken by all city transport modes, including direct and indirect uses.

b Parameter

Square meters of direct and indirect mobility space usage per capita.

c Methodology description

→ M4: Spatial analysis

The efficiency of mobility space usage is calculated by the ratio of the area covered by all city transport modes, including direct and indirect uses, to the total population of the city. The space usage is preferably measured by using spatial data and GIS, calculating the overlap of the shape file area for city transport and the one of the total area. An alternative is using existing data.

d Formula & Calculation method

Efficiency of land use, taken by all city transport modes, including direct and indirect uses

$$LUM = \frac{\sum_i(LD_i + LI_i)}{Cap}$$

LUM = Land use for mobility applications [m²]

LD_i = Direct Land use for mobility mode i [m²]

LI_i = Indirect Land use for mobility mode i [m²]

i = Mobility mode[#]

Cap = Capita or number of inhabitants in the city [#]

Efficiency refers indirectly to mobility output by referencing total population.

Direct land use by city transport refers to the area covered by transport infrastructure such as roads and streets and squares used to move people and for vehicles (public areas excluding parks, playgrounds and sport terrains). Airports and sea ports are excluded, inland ports included.

Indirect land use by city transport refers to indirect uses such as off-street parking areas, security areas, service areas, stations, inland port hubs, storage areas and distributions centers for city freight transport. Some suggestions of land use for the calculation:

DIRECT

Fast transit roads

Other roads

Railways

Inland ports and water ways

INDIRECT

Open parking

Private parking

Service area and petrol stations

Storage and logistic centres

Stations

e Source

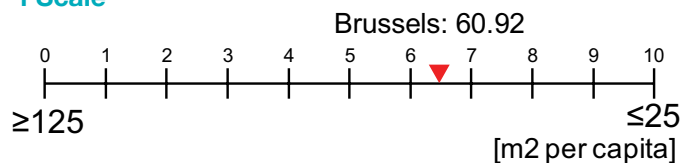
Methodology

The described methodology is based on information from the Victoria Transport Policy Institute (VPTI, “Evaluating Transportation Land Use Impacts”, (2012), p. 11-16)

Data sources:

- Direct and indirect land use for mobility can be extracted from GIS maps (for parking this net land use has to be multiplied with the number of levels).

f Scale



→ 0: ≥ 125 (m²/capita)

→ 10: ≤25 (m²/capita)

Land use for car traffic is almost the same amount as for housing (US; source: Litman). A minimum score of 125 m² is chosen.

g Notes

- Direct land use can also be calculated as a product of the total length of the infrastructure category (e.g. secondary roads) multiplied by a standard width per category.
- Indirect land use can also be based on the average unit surfaces for parking and service areas.

h Additional guideline

- The most important indirect land use are parking lots and petrol stations.
- Security areas and inland port hubs can be considered as indirect land use.
- The indicator focusses on land use and not on available space. As such, a station having 5 floors will count for the ground surface it occupies and

not 5 times this surface. Similarly, underground parking isn't counted.

- When needed an approximation of 800 m² can be used as average land use for service stations (source: database ATLAS of Brussels Region).
- To estimate the parking space usage, it is possible to multiply the number of parking spaces by their surface (~13 to 18 m²)

Emissions of greenhouse gases (GHG)

a Definition

Well-to-wheels GHG emissions by all city passenger and freight transport modes

b Parameter

Tonne CO₂ equivalent well-to-wheel emissions by urban transport per annum per capita.

c Methodology description

→ M3 Calculation (Traffic model)

This indicator measures the total emission of GHG per capita emitted by all city transport modes (freight and passenger, public and private). It is calculated by the conversion of the total vehicle-kilometers per capita into a corresponding amount of GHG.

Electricity consumption to recharge the electric (private) vehicles at home should be included. In this case estimation is required based on the number of electric vehicles identified / registered (car, motorcycles, bike, transporters...) and their expected electricity usage.

The total number of vehicle-kilometers is preferably collected by means of a traffic model. Alternative methods are field measurements (traffic counts on representative locations) or surveys (enquiring about people's trip behavior). Of course, if the vehicle-kilometers are available in existing city databases on mobility, they can be used too.

This indicator is calculated with the existing parameters for energy intensity, to be found in (inter)national databases. It measures how much energy is used to move both goods and people. Depending on the energy used per amount of fuel type (energy product), the CO₂ emissions are calculated. For other GHG, the CO₂ equivalent emissions are calculated based on the conversion factor per emission unit.

d Formula & Calculation method

The total amount of city transport GHG is calculated from the total amount of vehicle-kilometers per mode and per vehicle type in the following steps:

- **STEP 1:** converting vehicle-kilometers per type of vehicle and fuel into total emissions of the different GHG;
- **STEP 2:** converting the emissions of the different GHG into CO₂ equivalents;

- **STEP 3:** converting tailpipe emissions (pump-to-wheel) into well-to-wheel emissions.

This is expressed in the following formula:

$$G = \frac{(\sum_{ij} A_{ij} (\sum_k S_{jk} * I_{jk} * (C_k (1 + F_{ijk}) + W_k)))}{Cap}$$

G = Greenhouse gas emission [tons CO₂(eq) /cap. per year]

C_k = Tank to wheel CO₂ emission per energy type unit considered [kg/l or kg/kWh]

W_k = Well to tank CO₂ equivalent emission per energy type unit considered [factor]

A_{ij} = Activity volume (distance driven by transport mode *i* and vehicle type *j*) [million km per year]

S_{jk} = Share of fuel type *k* per vehicle type *j* [fraction]

I_{jk} = Energy intensity per distance driven for vehicle type *j* and fuel type *k* [l/km or MJ/km or kWh/km]

Cap = Capita or number of inhabitants in the city [#]

F_{ijk} = Non-CO₂ GHG correction (CO₂ equivalent) [factor]

k = Energy type (petrol, diesel, bio-fuel, electricity, hydrogen etc.) [type]

i = Transport mode (passenger car, tram, bus, train, motorcycle, inland vessel, freight train, truck, etc.) [type]

j = Vehicle class (if available specified by model (e.g. SUV, etc.) [type]

e Source

Data sources:

Specific national values will be preferably used for the CO₂ conversion factors from fuels in order to make calculations specific to the city under study. If no specific national values are available, international standard values can be found in literature.

National values are expected to be available for the factors S_{jk} and I_{jk}. F_{jk} can be found in international standards (i.e. GHG Protocol)

Factors C_k can be found, for example, in IPCC AR4 (2007), p. 212, Climate Change 2007 :

Industrial Designation or Common Name (years)	Chemical Formula	Lifetime (years)	Radiative Efficiency (W m ⁻² ppb ⁻¹)	Global Warming Potential for Given Time Horizon			
				SAR† (100-yr)	20-yr	100-yr	500-yr
Carbon dioxide	CO ₂	See below ^a	^b 1.4x10 ⁻⁶	1	1	1	1
Methane ^c	CH ₄	12 ^c	3.7x10 ⁻⁴	21	72	25	7.6
Nitrous oxide	N ₂ O	114	3.03x10 ⁻³	310	289	298	153
Substances controlled by the Montreal Protocol							
CFC-11	CCl ₃ F	45	0.25	3,800	6,730	4,750	1,620
CFC-12	CCl ₂ F ₂	100	0.32	8,100	11,000	10,900	5,200
CFC-13	CClF ₃	640	0.25		10,800	14,400	16,400
CFC-113	CCl ₂ FCClF ₂	85	0.3	4,800	6,540	6,130	2,700
CFC-114	CClF ₂ CClF ₂	300	0.31		8,040	10,000	8,730
CFC-115	CClF ₂ CF ₃	1,700	0.18		5,310	7,370	9,990
Halon-1301	CBrF ₃	65	0.32	5,400	8,480	7,140	2,760
Halon-1211	CBrClF ₂	16	0.3		4,750	1,890	575
Halon-2402	CBrF ₂ CBrF ₂	20	0.33		3,680	1,640	503
Carbon tetrachloride	CCl ₄	26	0.13	1,400	2,700	1,400	435
Methyl bromide	CH ₃ Br	0.7	0.01		17	5	1
Methyl chloroform	CH ₃ CCl ₃	5	0.06		506	146	45
HCFC-22	CHClF ₂	12	0.2	1,500	5,160	1,810	549
HCFC-123	CHCl ₂ CF ₃	1.3	0.14	90	273	77	24
HCFC-124	CHClF ₂ CF ₃	5.8	0.22	470	2,070	609	185
HCFC-141b	CH ₃ CCl ₂ F	9.3	0.14		2,250	725	220
HCFC-142b	CH ₃ CClF ₂	17.9	0.2	1,800	5,490	2,310	705
HCFC-225ca	CHCl ₂ CF ₂ CF ₃	1.9	0.2		429	122	37
HCFC-225cb	CHClF ₂ CF ₂ CF ₃	5.8	0.32		2,030	595	181
Hydrofluorocarbons							
HFC-23	CHF ₃	270	0.19	11,700	12,000	14,800	12,200
HFC-32	CH ₂ F ₂	4.9	0.11	650	2,330	675	205
HFC-125	CHF ₂ CF ₃	29	0.23	2,800	6,350	3,500	1,100
HFC-134a	CH ₂ FCF ₃	14	0.16	1,300	3,830	1,430	435
HFC-143a	CH ₃ CF ₃	52	0.13	3,800	5,890	4,470	1,590
HFC-152a	CH ₃ CHF ₂	1.4	0.09	140	437	124	38
HFC-227ea	CF ₃ CHF ₂ CF ₃	34.2	0.26	2,900	5,310	3,220	1,040
HFC-236fa	CF ₃ CH ₂ CF ₃	240	0.28	6,300	8,100	9,810	7,660
HFC-245fa	CHF ₂ CH ₂ CF ₃	7.6	0.28		3,380	1030	314
HFC-365mfc	CH ₃ CF ₂ CH ₂ CF ₃	8.6	0.21		2,520	794	241
HFC-43-10mee	CF ₃ CHFCH ₂ CF ₂ CF ₃	15.9	0.4	1,300	4,140	1,640	500
Perfluorinated compounds							
Sulphur hexafluoride	SF ₆	3,200	0.52	23,900	16,300	22,800	32,600
Nitrogen trifluoride	NF ₃	740	0.21		12,300	17,200	20,700
PFC-14	CF ₄	50,000	0.10	6,500	5,210	7,390	11,200
PFC-116	C ₂ F ₆	10,000	0.26	9,200	8,630	12,200	18,200

Factors W_k can be derived from tables like in [Federal Highway Administration, U.S. DOT, Handbook for estimating transportation greenhouse gases for integration into the planning process]:

Table 32. Lifecycle GHG Impacts of Sample Alternative Fuels

Fuel	Feedstock	WTP	PTW	WTW
		gCO ₂ e/mi		
Gasoline	U.S. Average	93	358	451
Ethanol (E85)	Corn	19	352	371
	Switchgrass	-233	352	119
CNG	NA NG: U.S. Average	119	272	391
LNG	NA NG: U.S. Average	118	273	391
Hydrogen	Central NG SMR	238	0	238
	Electrolysis, Renewables	3	0	3
Electricity	U.S. Mix	333	0	333
	California Mix	172	0	172
Diesel	U.S. Average	79	308	386
FTD	non-NA from NG	170	297	467
Biodiesel (B20)	Soybean	21	308	329
Renewable Diesel	Soybean	-207	298	92

Source: GREET.

Output: Lifecycle impacts of each fuel by grams of CO₂ per mile (gCO₂e/mi) as

- "well to pump (WTP)," – emissions to extract, produce, and transport
- "pump to wheel (PTW)," – tailpipe emissions; and
- "well to wheel (WTW)," – the sum of WTP and PTW.

f Scale



The indicator is scaled using the following graph:

- 0: ≥2,75 tons CO_{2(eq)}/cap.
- 10: 0 tons CO_{2(eq)}/cap.

g Notes

- A comprehensive approach is provided, including well to wheel emissions. By doing so, the total CO₂ impact is considered (global aspect), even if the production does not affect the city directly. This counts not only for fuel-driven modes; electricity production emissions (relevant for electricity production used by urban transport modes, if this is the case) have to be taken into account for road as well as rail transport.

- To avoid reflecting the city size and to validate all well-to-wheel aspects and the complete chain of mobility system-related solutions (such as distance shortening infrastructure works and mode choice shift), the unit "per capita" is required. Using vehicle-kilometer would mask certain solutions available in the transport market, resulting in fewer km driven for travel with same origin-destination.
- Gases other than CO₂ are included in the parameter using equivalent coefficients expressing the global warming potential (GWP) relative to the GWP of CO₂.

h Additional guideline

If the city does not have any (estimated) data related to distances driven by transport mode or any split over the respective transport mode the consumed fuels and electricity can be used.

Related to the fuel, the fuel consumption for transport can be estimated based on the fuel taken from the local fueling stations. Distance relation to fuel consumption estimated can be found at

<http://www.co2count.org.uk/defradoc.pdf>

http://www.ukconversionfactorscarbonsmart.co.uk/documents/2014%20Emission%20Factor%20Methodology%20Paper_FINAL-4Jul14.pdf

<http://www.ghgprotocol.org/files/ghgp/tools/co2-mobile.pdf>

For public transport the companies can report on the energy used (like fuels, electricity...) by their vehicles.

Based on the collected data above the CO₂ emissions can be calculated, considering that average a CO₂-equivalence correction value must be added for combustion related non-CO₂ gases:

- gasoline, diesel and LPG (and bio equivalents) : 1,0001
- CNG (and bio equivalents) : 1,02
- hydrogen is expected to produce no GHG gases : 0,00
- electricity : the non-CO₂ gases are expected to be included in the used CO₂ value : 1,00
- where coal is still used for direct fuel it is recommended to do a measurement test of the emissions on content of non-CO₂ gases with CO₂ equivalent impact while vehicle (train / boat / ...) is in operation. The related correction factor is to be used in the calculation.

Congestion and delays

a Definition

Delays in road traffic and in public transport during peak hours compared to free flow travel.

b Parameter

Weighted average per trip of the ratio of peak period travel times to free-flowing travel times with respecting rules inroad traffic and travel time adherence of public transport during peak hours on up to 10 major corridors for both transport modes.

c Methodology description

→ M5 Field measurement and M1: Analysis and external raw data.

For road congestion, the travel time measured along the 10 most representative urban corridors during morning and evening peak hours (averaged peak travel time per corridor) as opposed to the travel time in these corridors under free flow conditions.

For public transport, delays should be calculated based on running time adherence statistics from public transport companies for similar corridors and time periods as selected for car traffic. If the data is not available, these delays should be measured.

For road traffic, a cheaper and easier alternative is to use the data obtained for travel times during peak hours versus travel times in off-peak conditions obtained with online route planners (apps) which are based on real-time traffic conditions. (see also additional guidelines)

d Formula & Calculation method

$$CDI = MS_{road} * \frac{(\sum_{i=1}^{10} \frac{CTi + PHTi}{FFTi})}{\sum_{i=1}^{10} CTi} + MS_{pt} * \frac{(\sum_{j=1}^{10} (PTj * RTIj))}{\sum_{j=1}^{10} PTj}$$

CD_i = Congestion and delay index (percentage delay during peak hours) [% of delay]

CT_i = Number of car trips for commuting during peak hours on main road corridor i [#]

PHT_i = Travel time during peak hours on main road corridor i [minutes]

FFTi = Free flow travel time on main road corridor i [minutes]

PT_j = Number of public transport trips for commuting during peak hours on transit corridor j [#]

RTIj = Running time adherence index giving percentage of delays compared to time table during peak hours on transit corridor j [index]

MS_{road} = Modal share road [%]

MS_{pt} = Modal share public transport[%]

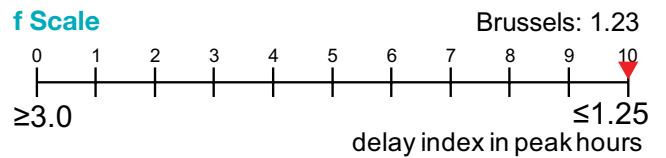
e Source

Data sources:

- Floating car measurement method for car traffic,

- Transit delay statistics for public transport.

f Scale



→ 0: ≥3.0[% delay] (relation peak hour time/normal condition travel time)

→ 10: ≤1.25[% delay](relation peak hour time/normal condition travel time)

g Notes

- Peak hour is the period at the beginning and end of the working day when large numbers of people are travelling to or from work. The corresponding hours are depending on citizen's habits and working legislations. They have to be defined for each city.
- The expression is in percentage deviation from free-flow traffic to avoid reflecting the city size and to validate all relevant transport measures, independent of the technology used.
- The methodology is proposed for peak hour conditions on a selection of 10 corridors to be as attainable as possible. It relies largely on the adequate choice of the ten corridors and of the portion considered to evaluate the travel time. The INRIX index for roads would be preferred for the road part of the indicator for cities where more elaborated measurements are available.

h Additional guideline

- If the city prefers to concentrate on road congestion, it can ignore the term related to public transport (delays). It might be particularly relevant when public transport have their own lanes so very small delays compared to their schedules.
- Particular attention is needed to define the free-flow conditions: in some cities the night isn't the most relevant period especially when vehicles tend to break the speed limits. In that case, measuring in the middle of the morning or afternoon might make more sense. Route mapping (e.g. web based) with link to actual traffic condition can be used to calculate traveling times if it considers legal conditions for free flow time.



Energy efficiency

a Definition

Total energy consumed for city transport

b Parameter

Total energy use by urban transport per passenger km and tonne km (annual average over all modes)

c Methodology description

➔ M4: Calculation (traffic model)

The total number of vehicle-kilometers is preferably collected by means of a traffic model. Alternative methods are field measurements (traffic counts on representative locations) or surveys (enquiring people's trip behavior). If the vehicle-kilometers are available in existing city databases on mobility, they can be used too.

This indicator is calculated with the existing parameters for energy intensity. The indicator represents the fuel used per unit of freight-kilometer and per unit of passenger-kilometer travelled by mode.

d Formula & Calculation method

Final energy use by urban transport per distance travelled (annual average over all modes).ed (annual average over all modes).

$$E = \frac{(\sum_{ij} A_{ij} (\sum_k S_{jk} * I_{jk} * EC_k))}{TV_{pass} + (TV_{fre} * 8)}$$

E = Energy consumption rate [MJ / km]

TV_{pass} = Transport volume passenger transport (passenger km) [million passenger km]

TV_{fre} = Transport volume freight transport [million ton km]

S_{jk} = Share of fuel type k per vehicle type j [fraction]

I_{jk} = Energy intensity per distance driven for vehicle type j and fuel type k [l/km or MJ/km or kWh/km]

A_{ij} = Activity volume (distance driven by transport mode i and vehicle type j) [million km per year]

EC_k = Fuel energy content for fuel k [l/km or MJ/km or kWh/km]

k = Fuel type [type]

i = Transport mode (passenger car, tram, bus, train, motorcycle, inland vessel, freight train, truck., etc.) [type]

j = Vehicle class (if available specified by model e.g. SUV, etc.) [type]

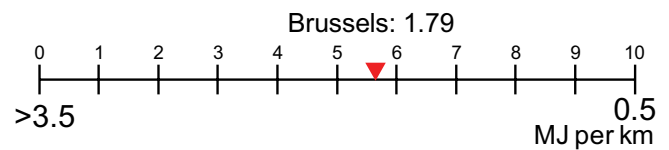
e Source

Data sources:

The use of specific national values is preferable for the energy content conversion factors of the fuels in order to make calculations specific to the city under consideration. National values are expected to be available for the factors S_{jk}, I_{jk} and A_{ij}.

If no specific national values are available, international standard values can be found in literature, see: United Nations (2007), Indicators of Sustainable Development: Guidelines and Methodologies

f Scale



➔ 0: ≥3.5 [Mjoule/transport unit km]

➔ 10: ≤0.5 [Mjoule/transport unit km]

g Notes

- This indicator relates final energy consumption to transport performance, as it is related to passenger and tonne kilometer (so the impact of shortening transport distances is not taken into account). The definition focuses on energy resources for moving vehicles (pump-to-wheel emissions). The use of other resources (such as materials for vehicle construction) and energy used for vehicle production and handling of vehicle wrecks are considered to be beyond the scope of urban governance. Thus elements, like electricity energy production losses in electricity plants, are not taken into account. The indicator measures the energy efficiency of the transport market.
- Passenger and freight transport are both included in the parameter. They have been balanced by introducing a factor of 1/8 for freight tonne kilometer. This factor is based on EU average loads and occupation rates for dominant mode (road): 12.7tonnes/truck and 1.5 persons/car, resulting in a factor of 1/8; see: http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Road_freight_transport_by_journey_characteristics and <http://www.eea.europa.eu/data-and-maps/indicators/occupancy-rates-of-passenger-vehicles-2/eu-occupancy-rates-of-passenger-vehicles>
- Different energy sources can be combined in one parameter by calculating the summed percentages of final energy use per source in relation to the total final energy using the theoretical energy content of the energy source.

h Additional guideline

If the city does not have any (estimated) data related to distances driven by transport mode or any split over the respective transport mode the consumed energy can be used.

Related to the fuel, the fuel consumption for transport can be estimated based on the fuel taken from the local fueling stations. Distance relation to fuel consumption estimated can be found at

<http://www.co2count.org.uk/defradoc.pdf>

http://www.ukconversionfactorscarbonsmart.co.uk/documents/2014%20Emission%20Factor%20Methodology%20Paper_FINAL-4Jul14.pdf

<http://www.ghgprotocol.org/files/ghgp/tools/co2-mobile.pdf>

For public transport the service companies can report on the energy used (like fuels, electricity, ...) by their vehicles.

Also the electric vehicles recharging at “home” must be estimated.

For this indicator an estimation of the distance driven is essential. This estimation can be derived from the following assumptions. These assumptions require some expert knowledge on number of vehicles in the city.

- Distance relation to fuel consumption estimated can be found at

<http://www.co2count.org.uk/defradoc.pdf>

http://www.ukconversionfactorscarbonsmart.co.uk/documents/2014%20Emission%20Factor%20Methodology%20Paper_FINAL-4Jul14.pdf

<http://www.ghgprotocol.org/files/ghgp/tools/co2-mobile.pdf>

- The relation passenger transport / freight transport can be identified through this table

OECD North America	0.09969
OECD Europe	0.14463
OECD Pacific	0.15724
FSU	0.13239
Eastern Europe	0.08613
China	0.28968
Other Asia	0.77691
India	0.63987
Middle East	1.43448
Latin America	0.42172
Africa	0.22874
Global ave.	0.19243

where freight (distance) = x times passenger (distance) ; the x value is very different per region and local expertise should assist in selecting the best applicable value. These are average values over all fuel types.

(source : smp-model-spreadsheet.xls at WBCSD)

The energy content of the fuels and the estimated distance driven allow to calculate the indicator

Opportunity for active mobility

a Definition

Options and infrastructure for active mobility, which refers to the use of the soft modes, namely walking and cycling.

b Parameter

The length of roads and streets with side walks and bike lanes and 30 km/h (20 mph) zones and pedestrian zones related to total length of city road network (excluding motorways).

c Methodology description

→ M4: : Analysis (spatial data) (GIS)

The indicator measures the spaces where active mobility is possible; therefore, this indicator is calculated as the percentage of the length of roads and streets with sidewalks and biking lanes and 30 km/h(20 mph) zones and pedestrian zones related to total length of city road network (excluding motorways). However if a length of road comes under more than one category it is only counted once.

This ratio is preferably obtained using spatial data and GIS. An alternative is using existing data of road length. Using GIS, it is possible to map both the length of the city network (without the motorways) and the length of the roads where active mobility is possible, which results in two different shape files that can be compared by performing an “identity operation”.



d Formula & Calculation method

$$R_{am} = 100 * \frac{(L_{sw} + L_{bl} + L_{z30} + L_{pz})}{L_{rn}}$$

R_{am} = Share of road length adapted for active mobility [%]

L_{sw} = Length of road network with sidewalks (not if in a pedestrian zone) [km]

L_{bl} = Length of road network with bike lanes (not if in a 30 km/h zone) [km]

L_{z30} = Length of road network in zone 30 km/h [km]

L_{pz} = Length pedestrian zone [km]

L_{rn} = Total length of city road network (excluding motorways) [km]

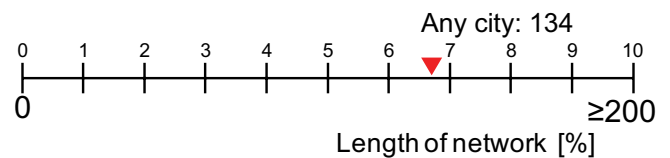
e Source

Methodology:

The Federal Environment Agency (2005), Quality targets and indicators for sustainable mobility, p. 37,

<https://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/3793.pdf>.

f Scale



→ 0: 0 [% road length]

→ 10: ≥200 [%]

g Notes

- The length of roads and streets with sidewalks or pedestrian zones plus the length of roads and streets having bike lanes or 30 km/h (20 mph) zones related to total length of city road network (excluding motorways).
- More and more “hybrid” vehicles (combining human power and an electric powered supporting motor) are being introduced in the market (light “car-like vehicles”). For practical reasons (difficulty of accounting for them within a parameter), specific facilities for these vehicles are not included in the indicator definition.

h Additional guideline

- Only facilities that meet the relevant standards should be included to avoid including unpractical sidewalks or bike lanes. Standards differ in different regions/countries, we advise to consider a minimum width of 0.60 meters for sidewalks and 0.75 meters for bike lanes as it is generally accepted in technical guidelines.

Intermodal integration

a Definition

Availability of intermodal connections and quality of the interchange facilities.

b Parameter

Number and frequency of the connections between the different transport modes and the reported good organization, information and physical access in the interchange facilities.

c Methodology description

M2 = Survey

The outline of the “Survey methodology” is described in the general part. The target population is users and non-users of intermodal connections.

- At least half of the interviews have to be addressed to users of the interchanges. A reasonable distribution between the different types of interchanges and interchange locations has to be obtained.

Questions refer to the availability of intermodal connections and essential elements of the interchange facilities and the quality of the facility and service provided. For example, for P+R the following questions might be formulated regarding satisfaction of users and non-users:

- Enough parking spaces
- Short distance to walk from parking space to station/public transport stop
- Safety of the parking garages or parking terrain
- Comfort and cleanliness of the parking garages or parking terrain
- Quality of trip information and route guidance
- Ease and speed of access to alternative modes (such as integration of ticketing system of parking and public transport)
- Frequency of public transport
- Shelter for climate conditions (rain, sun, heat, cold).

d Formula & Calculation method

$$QIntsc_{av} = \frac{\sum QIntsc_i}{n}$$

Where:

$QIntsc_{av}$ = Average score quality of interchanges

$QIntsc_i$ = Averaged score of the survey question i for quality of interchange

n = Number of persons in survey

e Source

Methodology:

LUYBEN, K., (2010), Designing robust road networks

OECD, (2010), Improving Reliability On surface

Transport Networks , Paris

f Scale



→ Scaling: : Reported average satisfaction on a scale of 0 to 100%.

→ 0: 0 [%]

→ 10: 100 [%]

g Notes

- The indicator is complementary with the comfort and pleasure indicator that accounts for the quality of the different transport modes separately.
- Bike sharing systems offered at public transport stops or stations and at P+R facilities are also considered.

Comfort and pleasure

a Definition

The physical and mental comfort of citizens while using the urban transports and services.

b Parameter

Average reported satisfaction about comfort of city transport and of pleasure of moving in the city area.

c Methodology description

→ M2: Survey

The outline of the “Survey methodology” is described in the general part.

- Comfort of urban public transport includes punctuality, crowding, quality of equipment, toilets (e.g. on trains and train stations), services (e.g. availability of food on trains), age of equipment, and availability of information. Comfort for biking and walking includes pavement condition and width of sidewalks and biking lanes. Comfort for car traffic refers to pavement condition of roads, quality traffic management. The overall quality of the transport system and completeness of the intermodal connections are also covered by this indicator. The indicator also refers to types or aspects of urban travel considered as enjoyable by the people travelling.

d Formula & Calculation method

The value is averaged survey score.

$$COMFsc_{av} = \frac{\sum COMFsc_i}{m}$$

$$COMFsc_i = \frac{\sum_j PCOMFsc_{ij}}{n_i}$$

Where:

$COMFsc_{av}$ = Averaged score of comfort and pleasure of city transport

$COMFsc_i$ = Averaged score of comfort and pleasure i.

$COMFsc_{ij}$ = Averaged score of comfort and pleasure for aspect i by person j.

n_i = Sample size for survey on aspect i

m = Number of aspects considered

i

- 1 Comfort and pleasure of freight service
- 2 Road comfort
- 3 Pleasure in car
- 4 Pleasure in motorcycle
- 5 Cycling Pleasure
- 6 Cycling Comfort
- 7 Walking pleasure
- 8 Walking comfort
- 9 Public transport pleasure
- 10 Public transport comfort
- 11 Car sharing pleasure
- 12 Car sharing comfort
- 13 Bike sharing pleasure
- 14 Bike sharing comfort

c Source

Methodology:

CIVITAS (2012), CIVITAS Elan Final Evaluation Report, p.213.

Concerning pleasure e.g.:

ORY, D.T. and L. MOKHTARIAN (2005), “When is Getting There Half the Fun? Modelling the Liking for Travel”, in: Transportation Research 39A(2-3), 2005, pp. 97-124.

f Scale



- Scaling: Reported average satisfaction on a scale of 0 to 100%.
- 0: 0 [%]
- 10: 100 [%]

g Notes

- Access to freight transport by citizens covers suitable package delivery services.
- Transportation planning is usually based on the assumption that time spent in travel is a cost. However, there are many indications that people consider a certain amount of mobility or certain types of travel to be enjoyable. Increasing the comfort and the services available (e.g. WiFi availability) can contribute largely to increase pleasure and better appreciation time while on the transports.

Security

a Definition

Risk of crime in urban transport.

b Parameter

Reported perception about crime-related security in the city transport system (including freight and public transport, public domain, bike lanes and roads for car traffic and other facilities such as car or bike parking)

c Methodology description

→ M2: Survey

Questions covering reported perception about crime-related security in city transport by general population based on topics:

- In public transport
- In public transport in the evening
- Walking
- Walking on the street at night
- Cycling
- Cycling at night
- Car jacking
- Risk for crime in car traffic
- Risk for theft in freight transport

d Formula & Calculation method

The value is the average survey score.

$$SECsc_{av} = \frac{\sum SECsc_i}{m}$$

$$SECsc_i = \frac{\sum_j SECsc_{ij}}{n_i}$$

Where:

SECsc_{av} = Averaged score of security of city mobility

SECsc_i = Averaged score of security of mode i

SECsc_{ij} = Averaged score of security question j related to mode i

i: Identification of transport mode i

n_i: Numbers of questions in survey related to transport mode i.

i

- 1 Public Transport
- 2 Cars
- 3 Motorcycles
- 4 Cycling
- 5 Walking

m: Numbers of persons in survey.

e Source

Methodology:

SUMMA and Transport & Mobility Leuven (2004), Operationalising Sustainable Transport and Mobility: The System Diagram and Indicators, p. 23, 136, <http://www.tmleuven.be/project/summa/summa-d3.pdf>.

f Scale



- Scaling: Reported average satisfaction on a scale of 0 to 100%.
- 0: 0 [%]
- 10: 100 [%]

g Notes

- Incidents include: property offences, physical offences against passengers and offences against operatives.
- Apart from the real security also the perceived security is an important issue in the frame of sustainable urban transport because security should give users confidence that they can use transport. The lack of this confidence can lead to non-compliance of mobility needs.
- Subjective security related to crime covers day and night situations in different transport mode environments such as (underground) parkings, streets and squares, stations and bus stops, public transport rides, ...
- Female transport users have to be represented in the survey sufficiently.

Annexes I.

WBCSD-SMP2.0 additional urban mobility parameters

As a result of our practical experience in the six demonstrator cities, we would like to recommend an additional set of parameters which we found useful to understand the city mobility and its development opportunities. Some of these parameters are needed for the indicator calculations such as modal split or occupancy rate. Others will influence the deployment of technological solutions such as smart cards, real time information etc.

We define them as parameters and not indicators because they do not define what is good or bad, and their optimization often depends on the city targets. For example some cities would like to increase the occupancy rate of public transport while other are struggling with overloaded public transport vehicles. Similarly, a modal split dominated by walking in developing countries is unfortunately often a sign of lack of infrastructure rather than good opportunity for active mobility.

The suggested parameters are:

Occupancy rate

This parameter is the average load factor of vehicles often defined per mode. Optimizing the occupancy rate of private and public vehicles is important to compromise between energy efficiency, transport costs and comfort. This parameter is related to energy efficiency, affordability and public finance indicators and impacts on the calculation results for GHG emissions, air pollution and energy efficiency.

Motorization rate (4W, 2W)

This parameter is often defined as the number of motorized vehicles per 1000 inhabitants. It usually increases with city economic development and it is a good parameter to interpret some indicator values (is it congested because there are too many vehicles or a lack of infrastructure?).

Smartphone penetration

In general the penetration of internet and cloud technologies is an important parameter for the deployment of real time information, smart ticketing/payment technologies, etc. A simple way to evaluate it can be to measure the percentage of the population having smartphones.

Modal split

It is the percentage of travelers using a specific transport mode. Modal split is an important parameter to define sustainability targets and balance the use of the different transport modes.

Vehicle miles travelled per capita

This parameter measures the vehicle distance travelled per inhabitant. It is an important parameter as it allows evaluating the efficiency of the mobility network in terms of distance travelled and occupancy rate of the vehicles. Besides, it can provide information on whether urban functions are well distributed over the city area.

Speed in the transport network

It is the percentage of travelers using a specific transport mode. Modal split is an important parameter to define sustainability targets and balance the use of the different transport modes. The speed in the transport network is influencing how much people will move. It is influenced by the speed of the vehicles, the size of the area covered with efficient mobility infrastructures for all modes (including biking and walking), the quality of the interchange between lines, the frequency of PT.

Car friendliness of the city center

As more and more cities would like to decrease the amount of negative impacts of private cars in the city center, they evaluate the car friendliness of their city center. It is related to the number of parking spaces available per km², parking tariff policy, existence of pedestrian zones or access restrictions based on the emission standard of the vehicle or related to the period of the day restrictions.

Availability of public transport cards.

This parameter measures the vehicle distance travelled per inhabitant. It is an important parameter as it allows evaluating the efficiency of the mobility network in terms of distance travelled and occupancy rate of the vehicles. Besides, it can provide information on whether urban functions are well distributed over the city area.



Annexes II.

WBCSD-SMP 2.0 topic presentation

This appendix has been developed as a result of our practical experience. Resilience has been transferred from quantitative indicator to “topic presentation” with city experts because resilience depends highly on the city geography and organization. Furthermore several types of resilience can be defined around themes such as people safety, economic reconstruction etc.



Resilience to disaster and ecological/ social disruptions

Kinds of (natural) disasters and strategies for disaster reduction

Depending on natural disasters, time allowed for evacuation and strategies for disaster reduction may be different. For example, for a tsunami after a big earthquake with its source in ocean, we could have 10 minutes to 60 minutes time for the evacuation to safe places. For flooding and hurricane, we might have much more time, since we can predict them in advance. And hence, safe and efficient evacuation may be relevant measures for disaster reduction. On the other hand, for a large earthquake with its source inland, we may not have any time for the evacuation, since a number of buildings would be collapsed immediately. And hence, facilitation of durable infrastructure may be more important than considering evacuation.

In general, resilience covers several aspects not only evacuation but also durable infrastructures, a rescue system etc. However, since we are concerning mobility in SMP 2.0, it might be better first mention that we limit our discussion on the resilience within evacuation that is most closely related to mobility.

Uncertainty and benchmark analysis

For safe and efficient evacuation, the operation of evacuation (assignment of people to evacuation shelters, share of mode use, evacuation timings, etc.) is important and depending on the operation, the performance of evacuation is different. Also, the performance of evacuation greatly relies on behaviors of people. However, behavior of people and details of evacuation operation have a lot of uncertainty and difficult to be taken into consideration. Considering these uncertainty, we sometime carry out a benchmark analysis based on the first-best evacuation operation in which the ability of evacuation infrastructure is evaluated assuming people perfectly obey the best evacuation operation.

Annexes III.

WBCSD-SMP 2.0 survey questions

Foreword

Please find below a suggested set of questions to evaluate the indicators;

Questions are to be selected and adapted depending on the cultural context and the mobility infrastructures in place.



This survey consists of 15 parts and described as follows;

I	BASIC DEMOGRAPHIC INFORMATION	Q01 – Q10
II	PREGNENCY	Q11 – Q12
III	OLDER TRAVELLERS	Q13
IV	PHYSICAL MOBILITY	Q14 – Q15
V	VISUAL IMPAIRMENT	Q16 – Q17
VI	COMMUTING	Q18 – Q24
VII	PUBLIC TRANSPORT	Q25 – Q30
VIII	CAR SHARING	Q31 – Q35
IX	BIKE SHARING	Q36 – Q40
X	PRIVATE VEHICLES	Q41 – Q50
XI	INTERMODAL	Q51 – Q58
XII	CYCLING	Q59 – Q64
XIII	WALKING	Q65 – Q70
XIV	FREIGHT DELIVERIES	Q71 – Q72
XV	PUBLIC AREAS	Q73 – Q79

City Mobility Survey- Questions

Welcome to the mobility survey. We value your input to help us better understand how mobility is viewed here in the city. We appreciate the time that you are giving and all input is used to help inform the city authorities to better develop sustainable mobility.

I BASIC DEMOGRAPHIC INFORMATION

Q01 Do you live in the city

(X) _____?

___A1-1. I live directly in the city of ___(X)___

___A1-2. I don't live directly in (X), but do commute to (X) regularly

___A1-3. I don't live directly in (X), but visit the city from time to time

___A1-4. I am (almost) never in (X)

Q02 Could you please give us your postcode for home and work / study

___A2-1. Home Postcode (_____)

___A2-2. Work / Study Postcode (_____)

Q03. What is your gender?

___A3-1. Male

___A3-2. Female

Q04. What is your age?

___A4-1. under 15

___A4-2. 15-17

___A4-3. 18-24

___A4-4. 25-34

___A4-5. 35-44

___A4-6. 45-54

___A4-7. 55-64

___A4-8. 65-74

___A4-9. 75 and over

Go to the end of survey if A4-1.(under 15) is selected.

Q05. What is the highest level of education you have completed?

___A5-1. Did not attend school

___A5-2. Technical or vocational college

___A5-3. Secondary School

___A5-4. High School

___A5-5. Degree or higher

Q06. Which of the following categories best describes your employment status?

___A6-1. Employed, working full time

___A6-2. Employed, working part time

___A6-3. Unemployed,

___A6-4. Student

___A6-5. Retired

___A6-6. Disabled, not able to work

___A6-7. Other

Q07. How many people currently live in your household? Answer 0, 1, 2, 3, 4, 5, 6 or more.

___A7-1. Adult

___A7-2. Under 18

Q08. How many vehicles does your household own?

Answer 0, 1, 2, 3, 4, 5 or more.

___A8-1. Cars

___A8-2. Motorcycles

___A8-3. Bicycles

Q09. What transport passes / permits do you own?

A9. _____

Q10. Do you have a driving license that allows you to drive the following? Please select all that apply.

___A10-1. Car

___A10-2. Motorcycle

___A10-3. Scooter

___A10-4. Other (e.g. truck, bus)

___A10-5. I don't have a driving licence

Go to Q13. if you did not select "A3-2. (female) and A4-3. to A4-5. (aged 18 – 44)".

II A PREGNANCY

Q11. Are you currently pregnant?

___A11-1. No.

___A11-2. 0 – 3 months

___A11-3. 4 – 6 months

___A11-4. more than 6 months

Go to Q13. if A11-1 is selected.

We would like to ask you some questions related to how easy (or difficult) you find it to use the different parts of the mobility system now that you are pregnant.

Q12. Please provide some more details on the provision of services that take into account your pregnancy.

Answer as follows;

a. Very Dissatisfied, b. Dissatisfied, c. Neutral, d. Satisfied, e. Very Satisfied

___Q12-1. Are you satisfied with the availability of parking spaces for expectant mothers?

___Q12-2. Are you satisfied with the access on foot to the parking places?

___Q12-3. Are you satisfied with the access on foot to the bus, tram and train stops?

___Q12-4. Are you satisfied with the benches and chairs in stations and at stops?

___Q12-5. Are there enough seating places in buses / trams?

___Q.12-6. Are there enough seating places in metro/trains?

___Q.12-7. Are you satisfied with the availability of benches and chairs around the city?

III OLDER TRAVELLERS

We would like to ask you some questions related to how easy (or difficult) you find it to use the different parts of the mobility system given your age.

Go to Q.14 if you did not select A4-8. (aged 65-74) or A4-9.(aged 75 and over).

Q13. As an older traveller how satisfied are you with the following ?

Answer as follows;

a.Very Dissatisfied, b.Dissatisfied, c.Neutral, d. Satisfied, e. Very Satisfied

___Q13-1. Quantity and location of parking spaces

___Q13-2. On foot accessibility of the parking places

___Q13-3. Accessibility of the public transport stops

___Q13-4. Access of the public transport vehicles at the stops or stations

___Q13-5. Quantity of seating places in the public transport

___Q13-6. Quality of the sidewalks

IV PHYSICAL MOBILITY

Q14 Do you suffer from personal physical mobility problems ?

___A14-1. Heavy

___A14-2. Medium

___A14-3. Light

___A14-4. None

Go to Q.16 if you selected A14-4. (None).

We would like to ask you some questions related to how easy (or difficult) you find it to use the different parts of the mobility system given your physical impairment.

Q15. Given your personal mobility issues how satisfied are you with the following?

Answer as follows;

a.Very Dissatisfied, b.Dissatisfied, c.Neutral, d. Satisfied, e. Very Satisfied

___Q15-1. Quantity and location of disabled parking spaces

___Q15-2. On foot accessibility of the disabled parking places

___Q15-3. Accessibility of the public transport stops

___Q15-4. Access of the public transport vehicles at the stops or stations

___Q15-5. Provision of space for your wheelchair on public transport

___Q15-6. Quality of the sidewalks

___Q15-7. Ease of crossing the roads

V VISUAL IMPAIRMENT

Q16. Do you suffer from visual impairment?

___A16-1. Blindness

___A16-2. Severe

___A16-3. Moderate

___A16-4. Mild or None

Go to Q.18 if you selected A16-4. (Mild or None).

We would like to ask you some questions related to how easy (or difficult) you find it to use the different parts of the mobility system given your visual impairment.

Q17 Given your visual impairment how satisfied are you with the following?

Answer as follows;

a.Very Dissatisfied, b.Dissatisfied, c.Neutral, d. Satisfied, e. Very Satisfied

___Q17-1. Accessibility of the public transport stops?

___Q17-2. Access of the public transport vehicles at the stops or stations

___Q17-3. Quality of the sidewalks?

___Q17-4. Are you satisfied with guidance and warning systems for visual disabled people along sidewalks?

VI COMMUTING

Q18 How many times did you travel last week to.....?

Answer as follows;

0, 1, 2, 3, 4, 5 or more.

___ **Q18-1.** Your place of work or study

___ **Q18-2.** For leisure or other reasons ?

Q19. What was your principle mode of transport for your commute?

Answer as follows;

a.Always, b.Most of the time, c.About half of the time, d.

Less than half of the time, e. never

___ **Q19-1.** Car

___ **Q19-2.** Motorcycle

___ **Q19-3.** Public transport

___ **Q19-4.** Ferry

___ **Q19-5.** Bike

___ **Q19-6.** Walking

___ **Q19-7.** Combination of modes (Car & public transport)

___ **Q19-8.** Combination of modes (Bike & public transport)

___ **Q19-9.** Combination of modes (Walk & public transport)

___ **Q20.** Could you please give us the following details about your main commute that you described above?

Q20. Could you please give us the following details about your main commute that you described above ?

Q20-1. Average travel distance (one way) in km

Q20-2. Average travel time to work in minutes

Q20-3. Average travel time to return home in minutes _____

Q20-4. How much extra time do you allow for the journey if you have to be certain of being at work/home for an important appointment

Q21. At what time of the morning does your daily commute typically start?

___ **A21-1.** Before 06:00

___ **A21-2.** 06:00-07:00

___ **A21-3.** 07:00-08:00

___ **A21-4.** 08:00-09:00

___ **A21-5.** After 09:00

Q22. At what time of the afternoon does your commute back home start?

___ **A22-1.** Before 15:00

___ **A22-2.** 15:00-16:00

___ **A22-3.** 16:00-17:00

___ **A22-4.** 17:00-18:00

___ **A22-5.** After 18:00

Q23. Do you feel restricted in terms of job market access because the mobility network is not connecting the place where you are living with the jobs you would like to apply for in less than 1 hour?

___ **A23-1.** Yes

___ **A23-2.** No

___ **A23-3.** Not Applicable

Q24. Were you restricted in the education choice for your children (primary/high school, university, apprenticeship, etc.) because of the duration of the commute to the university, school, etc?

___ **A24-1.** Yes

___ **A24-2.** No

___ **A24-3.** Not Applicable

VII PUBLIC TRANSPORT

We are interested to understand what people see as the most important aspect of public transport - what it is that encourages you to use it or inhibits you from using it.

Q25. How often do you use the following types of public transport?

Answer as follows;

a.(Almost) never, b.A few times a year, c.A few times a month, d. A few times a week, e. Daily

___ **Q25-1.** Trains

___ **Q25-2.** Metro

___ **Q25-3.** Trams

___ **Q25-4.** Buses

___ **Q25-5.** Ferry

Go to Q.27 if you selected d.(a few times a week) or e.(daily).

Q26. What are the main reasons for you not to use public transport regularly?

___ **A26-1.** Too expensive

___ **A26-2.** Too dirty

___ **A26-3.** Not comfortable (seats, noise, temperature)

___ **A26-4.** Not safe

___ **A26-5.** Threatened using it

___ **A26-6.** Not feel informed about routes and timetables

___ **A26-7.** Not reliable

___ **A26-8.** Its schedule do not fit to needs (e.g. not frequent or flexible enough)

___ **A26-9.** None of these

Q27. Could you please rank the following aspects of public transport from the thing that is most important to make you use public transport at the top.

- ___ **A27-1.** Cleanliness
- ___ **A27-2.** Availability of seats
- ___ **A27-3.** Comfort (seats, noise, temperature)
- ___ **A27-4.** Fare
- ___ **A27-5.** Real time information (routes, timetable and delays)
- ___ **A27-6.** Easy ticketing
- ___ **A27-7.** Buggy space available
- ___ **A27-8.** The punctuality of the public transport
- ___ **A27-8.** Comfort of stops whilst waiting (seats, lighting, shelter)
- ___ **A27-9.** Accessibility of the public transport vehicles, stops and stations
- ___ **A27-10.** Safe vehicles
- ___ **A27-11.** Feeling secure using public transport

Go to Q.29 if you did not select a.(Almost) never at Q25.

Q28. When on public transport how much do you.....

Answer as follows;

a.Dislike Extremely, b.Dislike Very Much, c.Neither Like nor Dislike, d. Like very much, e. Like Extremely

- ___ **Q28-1.** Enjoy riding the bus
- ___ **Q28-2.** Enjoy riding the train
- ___ **Q28-3.** Enjoy riding the metro
- ___ **Q28-4.** Enjoy riding other trams
- ___ **Q28-5.** Enjoy riding the ferry

Q29. How do you feel about the public transport?

Answer as follows;

a.Very Dissatisfied, b.Dissatisfied, c.Neutral, d. Satisfied, e. Very Satisfied

- ___ **Q29-1.** Cleanliness
- ___ **Q29-2.** Availability of seats
- ___ **Q29-3.** Comfort (seats, noise, temperature)
- ___ **Q29-4.** Fare
- ___ **Q29-5.** Real time information (routes, timetable and delays)
- ___ **Q29-6.** Easy ticketing
- ___ **Q29-7.** Buggy/luggage space available
- ___ **Q29-8.** The punctuality of the public transport
- ___ **Q29-9.** Comfort of stops whilst waiting (seats, lighting, shelter)
- ___ **Q29-10.** Accessibility of the public transport vehicles, stops and stations
- ___ **Q29-11.** Safe vehicles
- ___ **Q29-12.** Feeling secure using public transport

Q30. Do you feel unsafe because of potential physical attacks in the following situations?

Answer as follows;

a.Very unsafe, b.Rather much unsafe, c.Rather unsafe, d. quite safe, e. Very safe

- ___ **Q30-1.** Waiting for public transport at the stop or at the station during daytime
- ___ **Q30-2.** Waiting for public transport at the stop or at the station during nighttime
- ___ **Q30-3.** Being on board public transport during daytime
- ___ **Q30-4.** Being on board public transport during nighttime

VIII CAR SHARING

The next section is about car and bike sharing.

These are schemes where you become a member and can use the schemes' cars and bicycles for a per trip fee, sometimes free for a period of time.

When you share a friend's car to make a trip along with them this is considered as "car-pooling" and so is not included here.

Q31. Do you sometimes use a car-sharing scheme?

- ___ **A31-1.** (Almost) never
- ___ **A31-2.** A few times a year
- ___ **A31-3.** A few times a month
- ___ **A31-4.** A few times a week
- ___ **A31-5.** Daily

Go to Q.33 if you did not select A31-1.(Almost) never.

Q32. What are the main reasons for you not to use car share schemes regularly?

- ___ **A32-1.** I think it is too complicated (e.g. registration, use, billing)
- ___ **A32-2.** There are not enough vehicles available

- ___ **A32-3.** There are too few renting stations/ their locations are inconvenient
- ___ **A32-4.** Too expensive
- ___ **A32-5.** Vehicles are of poor quality
- ___ **A32-6.** Too few parking spaces
- ___ **A32-7.** Customer service is poor
- ___ **A32-8.** None of these

Q33. Please rank the following aspects of using car share schemes starting with the item which is most important to you.

- ___ **A33-1.** Easiness to use the shared car system
- ___ **A33-2.** Number of cars available
- ___ **A33-3.** Number and locations of the parking spaces
- ___ **A33-4.** Quality of the cars
- ___ **A33-5.** Cost of the system
- ___ **A33-6.** Cleanliness of the cars
- ___ **A33-7.** Quality of customer service

Go to Q.36 if you selected A31-1. (Almost) never at Q31.

Q34. When using shared transport facilities, how much do you enjoy riding a shared car ?

- A34-1.** Very much
- A34-2.** Rather much
- A34-3.** Rather
- A34-4.** Rather not
- A34-5.** Not at all.

Q35. How do you feel about car share schemes? Are you satisfied with the following items?

Answer as follows;

- a. Very Dissatisfied, b. Dissatisfied, c. Neutral, d. Satisfied, e. Very Satisfied
- Q35-1.** Easiness to use the shared car system
- Q35-2.** Number of cars available
- Q35-3.** Number and locations of the parking spaces
- Q35-4.** Quality of the cars
- Q35-5.** The cost of the system
- Q35-6.** Cleanliness of the cars
- Q35-7.** Quality of customer service

IX BIKE SHARING

Q36. Do you sometimes use the public bike shared schemes ?

- A36-1.** (Almost) never
- A36-2.** A few times a year
- A36-3.** A few times a month
- A36-4.** A few times a week
- A36-5.** Daily

Go to Q.38 if you did not select A36-1. (Almost) never.

Q37. What are the main reasons for you not to use Public bike share schemes regularly?

- A37-1.** I think it is too complicated (e.g. registration, use, billing)
- A37-2.** There are not enough bikes available
- A37-3.** There are too few renting stations/ their locations are inconvenient
- A37-4.** Too expensive
- A37-5.** Bikes are of poor quality
- A37-6.** The system is not flexible enough (e.g. bikes have to be returned to fixed stations)
- A37-7.** Customer service is poor
- A37-8.** None of these

Q38. Please rank the following aspects of using Public bike share schemes starting with the item which is most important to you.

- A38-1.** Easiness to use the shared bike system
- A38-2.** Number of bikes available
- A38-3.** Number and locations of the bike renting stations

- A38-4.** Quality of the bikes
- A38-5.** Cost of the system
- A38-6.** Cleanliness of the cars

Go to Q.41 if you selected A31-1. (Almost) never at Q31.

Q39. When using shared transport facilities, how much do you enjoy riding a shared bike ?

- A39-1.** Dislike extremely
- A39-2.** Dislike very much
- A39-3.** Neither like nor dislike
- A39-4.** Like very much
- A39-5.** Like extremely

Q40. How do you feel about comfort of Public bike share schemes? Are you satisfied with the following items?

Answer as follows;

- a. Very Dissatisfied, b. Dissatisfied, c. Neutral, d. Satisfied, e. Very Satisfied
- Q40-1.** Easiness to use the shared bike system
- Q40-2.** Number of bikes available
- Q40-3.** Number and locations of the bike renting stations
- Q40-4.** Quality of the bikes
- Q40-5.** The cost of the system
- Q40-6.** Cleanliness of the bikes

X PRIVATE VEHICLES

Go to Q.42 if you did not select A10-1.Car.

Q41. How often do you drive a car?

- A41-1.** (Almost) never
- A41-2.** A few times a year
- A41-3.** A few times a month
- A41-4.** A few times a week
- A41-5.** Daily

Go to Q.43 if you did not select A10-2.Motorcycle.

Q42. How often do you ride a motorcycle or scooter ?

- A42-1.** (Almost) never
- A42-2.** A few times a year
- A42-3.** A few times a month
- A42-4.** A few times a week
- A42-5.** Daily

Q43. Please rank the following aspects of driving on roads starting with the item which is most important to you.

- ___ **A43-1.** Traffic circulation
- ___ **A43-2.** Real time traffic information
- ___ **A43-3.** Signposting of directions and destinations for road users
- ___ **A43-4.** The lighting of urban streets for driving at night
- ___ **A43-5.** Quantity and location of parking spaces
- ___ **A43-6.** Accessibility of parking spaces by foot (e.g. no barriers like high pavements)
- ___ **A43-7.** Parking tariffs
- ___ **A43-8.** Quality of road infrastructure
- ___ **A43-9.** Traffic safety
- ___ **A43-10.** Feeling of personal security

Q44. What are the main issues that you see with regards to driving a car/motorcycle in the city?

- ___ **A44-1.** There are too many traffic jams
- ___ **A44-2.** The signposting is of poor quality
- ___ **A44-3.** Traffic information is insufficient
- ___ **A44-4.** There are too few parking spaces
- ___ **A44-5.** Parking fares are too expensive
- ___ **A44-6.** The streets are poorly lit at night
- ___ **A44-7.** The poor road infrastructure
- ___ **A44-8.** I fear physical attacks
- ___ **A44-9.** The risk to be involved in an accident
- ___ **A44-10.** None of these

Go to Q.46 if you did not selecte A10-1.Car.

Q45. In general, do you enjoy driving a car in the city?

- ___ **A45-1.** Dislike extremely
- ___ **A45-2.** Dislike very much
- ___ **A45-3.** Neither like nor dislike
- ___ **A45-4.** Like very much
- ___ **A45-5.** Like extremely

Go to Q.47 if you selected A8-1. a 0 (household no cars) at Q8.

Q46. How much do you feel afraid of the following situations that might happen?

Answer as follows;

a. Very much, b. Rather much, c. Rather, d. Rather not, e. Not at all

- ___ **Q46-1.** Your car being stolen during the day?
- ___ **Q46-2.** Your car being stolen at night?
- ___ **Q46-3.** Your belongings being stolen from your car during the day?
- ___ **Q46-4.** Your belongings being stolen from your car at night?

Go to Q.48 if you did not selecte A10-2. Motorcycle.

Q47. In general, do you enjoy driving a motorcycle/ scooter in the city?

- ___ **A47-1.** Dislike extremely
- ___ **A47-2.** Dislike very much
- ___ **A47-3.** Neither like nor dislike
- ___ **A47-4.** Like very much
- ___ **A47-5.** Like extremely

Go to Q.49 if you selected A8-2. a 0 (household no motorcycles) at Q8.

Q48. How much do you feel afraid of the following situations that might happen?

Answer as follows;

a. Very much, b. Rather much, c. Rather, d. Rather not, e. Not at all

- ___ **Q48-1.** Your motorcycle/scooter being stolen during the day?
- ___ **Q48-1.** Your motorcycle/scooter being stolen at night?
- ___ **Q48-1.** Your belongings being stolen from your motorcycle/scooter during the day?
- ___ **Q48-1.** Your belongings being stolen from your motorcycle/scooter at night?

Go to Q.50 if you selected A10-5. I don't have a driving licence.

Q49. How do you feel about driving in the city? How satisfied are you with the following items?

Answer as follows;

a. Very Dissatisfied, b. Dissatisfied, c. Neutral, d. Satisfied, e. Very Satisfied

- ___ **Q49-1.** Real time traffic information
- ___ **Q49-2.** Signposting of directions and destinations for road users
- ___ **Q49-3.** The lighting of urban streets for driving at night
- ___ **Q49-4.** Quantity and location of parking spaces
- ___ **Q49-5.** Accessibility of parking spaces by foot (e.g. no barriers like high pavements)
- ___ **Q49-6.** Parking tariffs
- ___ **Q49-7.** Quality of road infrastructure
- ___ **Q49-8.** Traffic safety
- ___ **Q49-9.** Feeling of personal security

Q50. Do you feel unsafe because of potential physical attacks in the following situations?

Answer as follows;

a. Very unsafe, b. Rather much unsafe, c. Rather unsafe, d. Quite safe, e. Very safe

- ___ **Q50-1.** Driving a car during daytime
- ___ **Q50-2.** Driving a car at night
- ___ **Q50-3.** Driving a motorcycle/scooter during daytime
- ___ **Q50-4.** Driving a motorcycle/scooter at night

XI INTERMODAL

Q51. How often do you make an intermodal trip (with more than one transport mode e. g using bus and train)?

- A51-1.** (Almost) never
- A51-2.** A few times a year
- A51-3.** A few times a month
- A51-4.** A few times a week
- A51-5.** Daily

Q52. Please rank the following aspects of making intermodal trips starting with the item which is most important to you.

- A52-1.** Availability/Location of connecting points
- A52-2.** Distance to walk from mode to mode
- A52-3.** Quality of trip information and route guidance
- A52-4.** Integration of ticketing system of bus, tram, train
- A52-5.** Integration of time schedules of bus, tram, train
- A52-6.** Frequency of connecting public transport
- A52-7.** Signposting to find connecting mode

Q53. I don't make intermodal trips more often because.....

- A53-1.** I do not have the information about the other modes to be able to effectively make connections
- A53-2.** It is difficult to physically make the connections because of distance or steps
- A53-3.** The waiting time between the two modes is too long
- A53-4.** It is difficult to find the locations for the other modes
- A53-5.** My ticket is only valid on one mode of transport
- A53-6.** I have to change vehicle/mode too often to be able to make my journey effectively
- A53-7.** I fear my car will be stolen/damaged/broken into if I switch to another mode
- A53-8.** None of these

Q54. Can you indicate how satisfied you are with the quality of the intermodal connectivity ?

Answer as follows;

a. Very Dissatisfied, b. Dissatisfied, c. Neutral, d. Satisfied, e. Very Satisfied

- Q54-1.** Availability/Location of connecting points
- Q54-2.** Distance to walk from mode to mode
- Q54-3.** Quality of trip information and route guidance
- Q54-4.** Integration of ticketing system of bus, tram, train
- Q54-5.** Integration of time schedules of bus, tram, train
- Q54-6.** Frequency of connecting public transport
- Q54-7.** Signposting to find connecting mode
- Q54-8.** Number of changes necessary to complete your journey
- Q54-9.** Number of alternative methods available to make your journey

Q55. Do you have a smartphone that you use on a daily basis?

- A55-1.** Yes
- A55-2.** No

Go to Q59 if A55-2 (No) is selected.

Q56. Are you aware of the mobility tools offered on the smartphone for your city ?

- A56-1.** Yes
- A56-2.** No

Go to Q59 if A56-2 (No) is selected.

Q57. Do you use the mobility tools that are available on your smartphone ?

- A57-1.** Yes
- A57-2.** No

Go to Q59 if A57-2 (No) is selected.

Q58. Please list the mobility tools that you use on your phone (either web based or apps)

- A58-1.** (To be filled in for city App a)
- A58-2.** (To be filled in for city App b)
- A58-3.** (To be filled in for city App c)

XII CYCLING

Q59. How often do you ride a bicycle ?

- A59-1.** (Almost) never
- A59-2.** A few times a year
- A59-3.** A few times a month
- A59-4.** A few times a week
- A59-5.** Daily

Go to Q61. if A59-5. (Daily) is selected.

Q60. What are the main reasons for you not ride a bike in the city more often?

- A60-1.** There are too few dedicated lanes for biking
- A60-2.** The bike lanes are of poor quality
- A60-3.** The way other road users treat cyclists
- A60-4.** The roads are of poor quality for biking
- A60-5.** The bicycle parking facilities in the city are too few and too unsafe
- A60-6.** I don't feel safe from physical attacks
- A60-7.** The risk to be involved in an accident
- A60-8.** None of these

Q61. Please rank the following aspects of cycling in the city starting with the item which is most important to you.

- A61-1.** Availability of dedicated lanes for biking
- A61-2.** Width of bike lanes
- A61-3.** Quality of road surface of the bike lanes
- A61-4.** The way other road users treat cyclists when on mixed use roads
- A61-5.** Signposting of directions and destinations for biking
- A61-6.** Lighting of biking facilities and urban streets at night
- A61-7.** Number and the location of bicycle parking facilities in the city
- A61-8.** Security of the bicycle parking facilities
- A61-9.** Feeling of personal security
- A61-10.** Traffic safety

Q62. How do you feel about cycling?

- A62-1.** Dislike extremely
- A62-2.** Dislike very much
- A62-3.** Neither like nor dislike
- A62-4.** Like very much
- A62-5.** Like extremely

Go to Q.65 if A59-1. ((Almost) never) is selected.

Q63. How do you feel about comfort of cycling?

Answer as follows;

a. Very Dissatisfied, b. Dissatisfied, c. Neutral, d. Satisfied, e. Very Satisfied

- Q63-1.** Availability of dedicated lanes for biking
- Q63-2.** Width of bike lanes
- Q63-3.** The quality of road surface of the bike lanes
- Q63-4.** The way other road users treat cyclists when on mixed use roads
- Q63-5.** Signposting of directions and destinations for biking
- Q63-6.** Lighting of biking facilities and urban streets at night
- Q63-7.** Number and the location of bicycle parking facilities in the city
- Q63-8.** Security of the bicycle parking facilities

Q64. Do you feel unsafe because of potential physical attacks in city streets when doing the following?

Answer as follows;

a. Very unsafe, b. Rather much unsafe, c. Rather unsafe, d. Quite safe, e. Very safe

- Q64-1.** Riding a bike during daytime
- Q64-2.** Riding a bike at night

XIII WALKING

Q65. How often do you ride a bicycle ?

- A65-1.** (Almost) never
- A65-2.** A few times a year
- A65-3.** A few times a month
- A65-4.** A few times a week
- A65-5.** Daily

Go to Q67 if A65-5. (Daily) is selected.

Q66. What are the main reasons for you not to walk regularly?

- A66-1.** There are too few sidewalks
- A66-2.** The sidewalks are of poor quality
- A66-3.** There are too few car free areas
- A66-4.** The signposting of directions and destinations for walking aren't good enough
- A66-5.** The sidewalks are poorly lit
- A66-6.** I fear personal attacks
- A66-7.** None of these

Q67. Please rank the following aspects of walking in the city starting with the item which is most important to you.

- A67-1.** Availability of sidewalks in the city
- A67-2.** Availability of car free streets in the city
- A67-3.** Width of sidewalks in the city

A67-4. Quality of the pavement of the sidewalks in the city

A67-5. Signposting of directions and destinations for walking

A67-6. Lighting of sidewalks and urban streets at night

A67-7. Feeling of personal security

Q68. How do you feel about walking?

Answer as follows;

a. Dislike extremely, b. Dislike very much, c. Neither like nor dislike, d. Like very much, e. Like extremely

Q68-1. Do you in general enjoy walking ?

Q68-2. Do you sometimes go for a walk just for pleasure?

Go to Q71. if A65-1. ((Almost) never) is selected.

Q69. How do you feel about comfort of walking? Are you satisfied with the following items:

Answer as follows;

a. Very Dissatisfied, b. Dissatisfied, c. Neutral, d. Satisfied, e. Very Satisfied

- ___ **Q69-1.** Availability of sidewalks in the city
- ___ **Q69-2.** Availability of car free streets in the city
- ___ **Q69-3.** Width of sidewalks in the city
- ___ **Q69-4.** Quality of the pavement of the sidewalks in the city
- ___ **Q69-5.** Signposting of directions and destinations for walking
- ___ **Q69-6.** Lighting of sidewalks and urban streets at night

Q70. Do you feel unsafe because of potential physical attacks in city streets when doing the following?

Answer as follows;

a. Very unsafe, b. Rather much unsafe, c. Rather unsafe, d. Quite safe, e. Very safe

- ___ **Q70-1.** Walking during daytime
- ___ **Q70-2.** Walking at night

XIV FREIGHT DELIVERIES

We would like to understand if you use home deliveries at all and, if you do use them, what your overall feel is of these services

Q71. How often do you use package delivery services?

- ___ **A71-1.** (Almost) never
- ___ **A71-2.** A few times a year
- ___ **A71-3.** A few times a month
- ___ **A71-4.** A few times a week
- ___ **A71-5.** Daily

Go to Q73. if A71-1. (Almost) never is selected.

Q72. Are you satisfied overall with delivery services ?

Answer as follows;

a. Very Dissatisfied, b. Dissatisfied, c. Neutral, d. Satisfied, e. Very Satisfied

- ___ **Q72-1.** How satisfied are you with the service
- ___ **Q72-2.** Flexibility of delivery times
- ___ **Q72-3.** Ability to arrange alternative delivery locations

XV PUBLIC AREAS

Q73. How often do you make use of a public square or a meeting place in a street in the city to spend some time there (just walking around to meet people, sitting on a terrace or bench, with children at a playground,...)?

- ___ **A73-1.** (Almost) never
- ___ **A73-2.** A few times a year
- ___ **A73-3.** A few times a month
- ___ **A73-4.** A few times a week
- ___ **A73-5.** Daily

Go to Q75. if A73-5. (Daily) or A73-4. (A few times a week) is selected.

Q74. What are the main reasons for you not to make use of public areas in the city more regularly?

- ___ **A74-1.** They aren't child friendly
- ___ **A74-2.** There aren't enough public areas such as plazas, car free shopping areas or parks.
- ___ **A74-3.** They are not easily accessible
- ___ **A74-4.** There aren't enough playgrounds
- ___ **A74-5.** There aren't enough public areas allowing physical activities
- ___ **A74-6.** There isn't enough greenery in the public area
- ___ **A74-7.** There aren't enough activities such as markets or festivals
- ___ **A74-8.** I feel unsafe in public areas

- ___ **A74-9.** They are too crowded
- ___ **A74-10.** None of these

Q75. Please rank the following aspects of public areas in the city starting with the item which is most important to you.

- ___ **A75-1.** Availability of car free shopping streets or other pedestrian friendly shopping streets
- ___ **A75-2.** Availability of public areas (squares, parks, plazas) open to everyone to stroll or rest
- ___ **A75-3.** Availability of play grounds
- ___ **A75-4.** Availability of public areas that allow physical activity
- ___ **A75-5.** Child-friendliness
- ___ **A75-6.** Accessible for everyone
- ___ **A75-7.** Activities Markets, festivals, ...
- ___ **A75-8.** Possibility of social interaction
- ___ **A75-9.** Greenery
- ___ **A75-10.** Safety
- ___ **A75-11.** No overcrowding

Q76. How much do you enjoy using public areas in the city?

- ___ **A76-1.** Dislike extremely
- ___ **A76-2.** Dislike very much
- ___ **A76-3.** Neither like nor dislike
- ___ **A76-4.** Like very much
- ___ **A76-5.** Like extremely

Q77. How satisfied are you with the public areas in the city?

Answer as follows;

- a. Very Dissatisfied, b. Dissatisfied, c. Neutral, d. Satisfied, e. Very Satisfied

___ **Q77-1.** Availability of car free shopping streets or other pedestrian friendly shopping streets

___ **Q77-2.** Availability of public areas (squares, parks, plazas) open to everyone to stroll or rest

___ **Q77-3.** Availability of play grounds

___ **Q77-4.** Availability of public areas that allow physical activity

Q78. How satisfied are you with the following items regarding the quality of public spaces in the city?

Answer as follows;

- a. Very Dissatisfied, b. Dissatisfied, c. Neutral, d. Satisfied, e. Very Satisfied

___ **Q78-1.** Child-friendliness

___ **Q78-2.** Accessible for everyone

___ **Q78-3.** Activities Markets, festivals, ...

___ **Q78-4.** Possibility of social interaction

___ **Q78-5.** Greenery

___ **Q78-6.** Safety

___ **Q78-7.** Crowding

Q79. Do you feel unsafe when using public spaces in the city ?

Answer as follows;

- a. Very unsafe, b. Rather much unsafe, c. Rather unsafe, d. Quite safe, e. Very safe

___ **Q79-1.** During the day

___ **Q79-2.** During the night

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