Methodology and indicator calculation method for

sustainable urban mobility

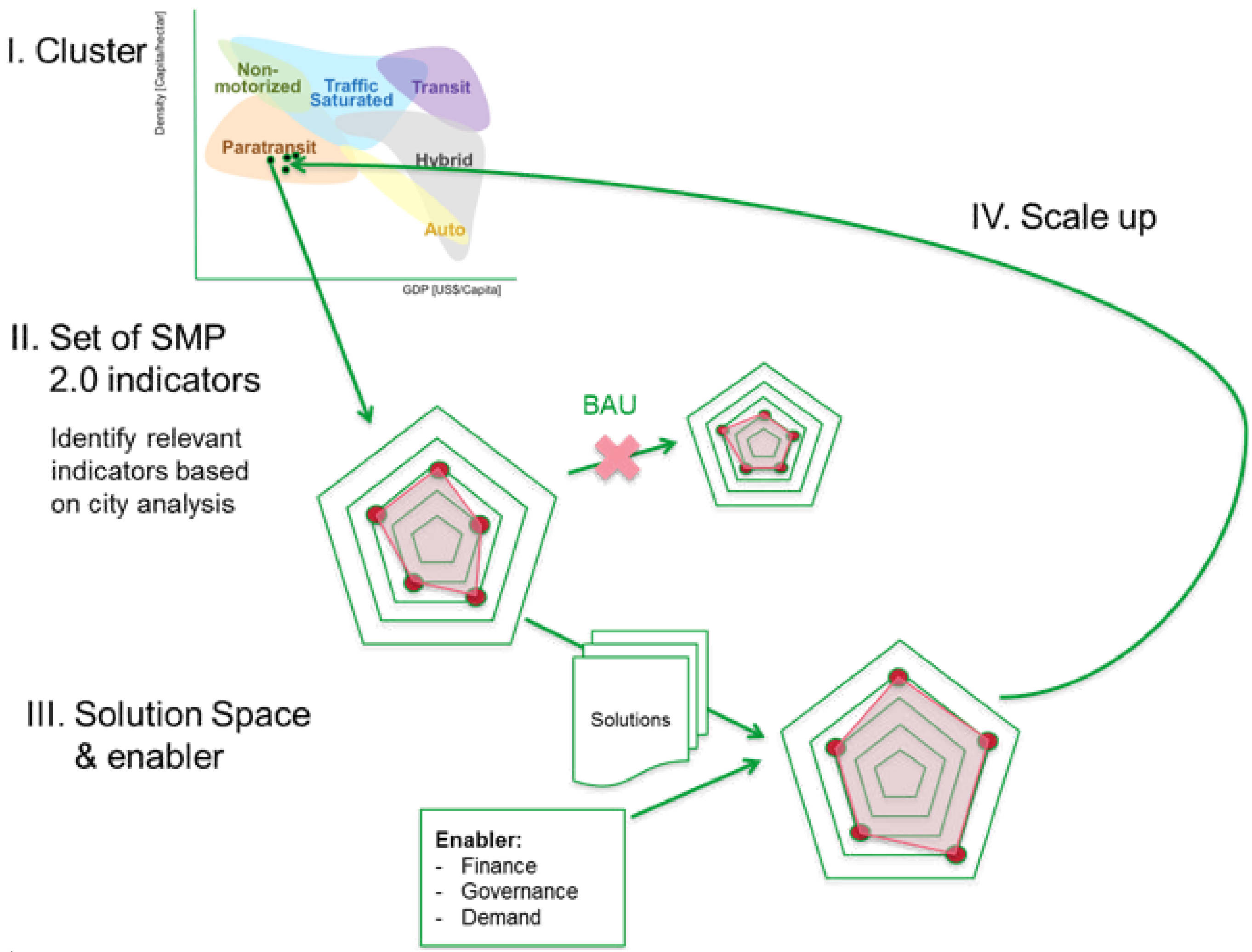
World Business Council for Sustainable Development
Sustainable Mobility Project 2.0 (SMP2.0)
Indicators Work Stream

wbcsd mobility

Preface

The Indicators Work Stream (WS2) of the Sustainable Mobility Project 2.0 (SMP2.0) within the World Business Council for Sustainable Development (WBCSD) has commissioned Oran Consulting to define with WS2 a set of indicators measuring the potential for sustainable mobility in cities.

The indicator set is a tool for cities to evaluate the current situation, understand the natural evolution of sustainable mobility (business as usual, or BAU) and to evaluate the impact of selected solutions, for example those from the solution toolbox that SMP2.0 prepared for that purpose. The indicators provided are not necessarily discreet and may need to be considered together. For instance, congestion, noise and travel time are all usually related, though noise will rise with faster moving traffic unless mitigation measures are taken. For some indicators, the relevant interpretation is only possible when joint consideration of a small set is made. For example, when considering public transport, it is necessary to take into account the entire group consisting of occupancy rate, affordability and public finance.



Additionally, a good experience in one city can potentially be used to help other similar cities improve the situation within their own city (scale up).

To truly reflect the mobility situation of a city, all indicators should be calculated (or, at a minimum, estimated). This allows for a holistic understanding of the current situation and a leads to a robust process in focusing efforts on developing and applying solutions. The start of this process sits with the city selecting the indicators it most wants to improve considering its mobility situation. If the city has its own set of indicators for mobility, city-specific indicators can also be added to the set used.

If the city is facing problems collecting the required data, it is possible for it to use approximations of the indicator methodology (some are included in the report) or, where it exists, to use its own methodology to calculate the indicator value.

Although the indicators are not designed to compare sustainable mobility between cities, similar cities might use the indicator set to understand where they can further improve their local situation.

CONTENTS

Executive Summary

The work presented in this report aimed to develop a comprehensive set of sustainable mobility indicators for cities. The indicators are described with SMART (specific, measurable, achievable, relevant, time-bound) 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. As an additional benefit, this exercise will reveal the measures impacting the most efficiently on specific indicators and thus allow other cities to select the ones they need 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 (indicators on greenhouse gasses, energy efficiency, etc.)
2. Quality of life in the city (indicators on safety, access, etc.)
3. Economic success (indicators on economic opportunity, public finance, congestion, etc.)

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

4. Mobility system performance (indicators on intermodal connectivity, occupancy rate, etc.)

The research carried out within the Sustainable Mobility Project 2.0 has resulted in the following set of 22 indicators:

- Emissions of greenhouse gases (GHG)
- Net public finance
- Congestion and delays
- Economic opportunity
- Commuting travel time
- Mobility space usage
- Quality of public area
- Access to mobility services
- Traffic safety
- Noise hindrance
- Air polluting emissions
- Comfort and pleasure
- Accessibility for mobility-impaired groups
- Affordability of public transport for the poorest group
- Security
- Functional diversity
- Intermodal connectivity
- Intermodal integration
- Resilience to disaster and ecological/social disruptions
- Occupancy rate
- Opportunity for active mobility
- Energy efficiency

A measurable parameter has been defined for each indicator and is described with the methodology to quantify it. Methodologies have been developed to include all modes of transport for passengers and freight and to be as attainable as possible for cities in worldwide. In addition to this report, an Excel-based calculation tool is available for interested city authorities. It has been developed to automatize the calculation process based on the input data. For some parameters, calculations are based on data available in existing databases (e.g. on *public finance*), by field measurements (e.g. noise hindrance) or in population surveys (e.g. *commuting travel time*). For others, it is proposed to work with processed input data, either via a geographic information system (GIS) (e.g. number of people living within the catchment area of public transport stops) or traffic modelling (e.g. parameters based on vehicle-kilometers with certain types of vehicles). Cities that cannot deploy the software packages concerned have to rely on unprocessed data sources as a second option.

The project proposes to represent the performance of the mobility system in the city in a “radar view” or “spider chart”. As such cities can identify their strengths and weaknesses in specific areas and launch targeted actions.

This report documents indicator definitions, parameters and methodologies to be used by cities to identify their sustainable mobility performance. It has been developed on behalf of the Indicator Work Stream of the Sustainable Mobility Project 2 (SMP2.0), a World Business Council for Sustainable Development (WBCSD) sector project.

WBCSD SMP2.0 proposes a set of 22 indicators developed within 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.

Cities can use the report as a guideline and support for indicator information gathering and data treatment. It contains practical information on the proposed data collecting methods and the calculation of the parameters of each of the indicators. For the data treatment, an Excel calculation sheet has been developed. This report also explains how to use this calculation sheet.

I Introduction

The structure of the report is as follows:

More details on the background of the indicators can be found in additional documents A, B, C (working documents) on each of the indicators:

- Literature on indicator definitions
- SMART assessment of parameters
- Exploration of parameter values

Additional documents D and E are practical tools to obtain the indicator values for a city.

- Annex D of this report contains the survey forms.
- Annex E is a calculation tool sheet for the different parameters as well as for the overall result per city.

II Why work with indicators

Why should cities work with the proposed indicators?

❶ A set of indicators with a sound basis

WBCSD SMP2.0 proposes a set of 22 indicators developed after a process of intensive work and within 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).

The comprehensive set of indicators resulting from this process is valid for cities at any stage of economic development.

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

Cities need to assess the set of 22 indicators in order to obtain a balanced coverage of their mobility performance over the full scope of the sustainability dimensions. By using the full set of 22 indicators, cities can identify the strengths and weaknesses of their mobility system, including freight and passenger transport. Using the indicator scores, the city can identify in which area improvements are recommended by comparing score levels between parameters. The scaling provided also allows cities to have a reference compared to other cities. When going deeper into the parameter calculation, cities might even identify the geographical areas (corridors, neighborhoods, etc.) and more specific aspects (e.g. facilitating access to a certain transport mode, etc.) for action.

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

Using the indicator set, the city can identify the indicators for which the score is low. Having selected the indicators to work on, the city can match these indicators with a reduced set of solutions elaborated by the WBCSD SMP2.0 Solutions Work Group. This indicator set allows an ex-ante evaluation of the implementation of envisaged measures to be taken by the city and/or solutions proposed by the industry on the different sustainability aspects. In doing so, well-evaluated decisions can be made.

Representing the performance of the mobility system in the city in a “radar view” or “spider chart” also allows the city to identify its strengths. This can be used to demonstrate “good practices” as a reference for other cities.

❹ A set of indicators allowing for the monitoring of progress

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

❺ A set of indicators that is technology neutral

The indicators do not favor any technology. They are generally applicable and neither disfavor upcoming technologies not yet included in the set nor old technologies that are the only ones the city can afford. It allows the city to choose the solutions best suited to its economic, social and technical resources.

❻ A set of indicators that is mode neutral

The indicators also do not favor any particular mode, so that every mode is assessed by the same criteria. Again, it allows the city to choose the solutions that are the best suited to the economic, social and technical resources of the city, rather than forcing solutions into one particular mode.

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 climate change).

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 safety and security).

On the one hand, mobility impacts the economic success and quality of life in the city (for example, traffic noise impacts noise hindrance, having a local impact on the quality of life in the city, while travel time for commuters impacts economic success in the city) and impacts the global environment on a larger geographical scale (for example, GHG emissions affect climate change and thus have a global impact. On the other hand, mobility can only function based on some resources, as much on the global scale as on the local scale: for example, energy impacts the global environment, public finance impacts economic success, and the diversity of spatial functions impacts quality of life. Thus the three sustainability dimensions refer to some impacts and the use of resources caused by urban mobility.

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 22 indicators has been identified to comprehensively describe sustainable mobility in cities. Four dimensions of sustainable mobility are represented in the table below:

Set of 22 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	
Traffic Safety	**Safety**	Q	
Access to mobility services	**Access**	Q	
Quality of public area	**Public area**	Q	
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
Resilience for disaster and ecologic /social disruptions	**Resilience**	G	S
Intermodal connectivity	**Intermodal connectivity**	S	
Intermodal integration	**Intermodal integration**	S	
Occupancy rate	**Occupancy rate**	S	
Comfort and pleasure	**Comfort and pleasure**	S	Q
Security	**Security**	S	Q

Table.1: Overview of the 22 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 (indicators on *greenhouse gasses, energy,* etc.)

Q Quality of life in the city (indicators on *safety, access,* etc.)

E Economic success (indicators on *economic opportunity, public finance,* etc.)

The fourth dimension refers more directly to the performance of the mobility system itself:

S Mobility system performance (indicators on *intermodal connectivity, occupancy rate,* etc.)

In some cases indicators may impact on two, three or even four sustainable mobility dimensions. For example, congestion increases air pollution (G), provokes a waste of time for the passenger (Q) and has high associated costs (E). For simplicity, we have represented the two main ones in the table.

The first indicator mentioned in table 1 is *emissions of greenhouse gases*. Many international organizations – and also more and more city authorities – regard this indicator of as being of crucial importance to urban mobility policy. It directly refers to the impact on climate change.

Net public finance is an indicator referring to the economic demands of the mobility system. *Economic opportunity* and *commuting travel time* are considered as indicators for the economic output (or impact) of urban mobility. Commuting travel time refers to a cost that may endanger economic development in the city (because of the delocalization of people and companies due to a bad score). Economic opportunity refers to economic development in the city as directly related to the transport sector. Apart from their economic impact, these two indicators have a social impact too: economic opportunity is related to job creation and commuting travel time is also an indicator of quality of life.

The impact of mobility on quality of life is regarded as a growing concern for citizens and city authorities: 12 indicators refer to this dimension. *Quality of public area, access to mobility services, traffic safety, noise hindrance* and *air polluting emissions* are selected as mere quality of life indicators. Traffic (un)safety and air polluting emissions are classified in this group because they are a direct threat to human life. Moreover (traffic) noise is regarded increasingly as an aspect of human health, and even less harmful lower noise emissions might cause annoyance. But not all quality of life indicators refer to negative impacts: a well-organized mobility system might enhance the quality of public area and clearly guarantee a high level of *access to mobility services*, both important issues contributing to the social life in the city.

In total, 11 indicators refer to mobility system performance. *Accessibility for mobility-impaired groups, affordability of public transport for the poorest group, comfort and pleasure and security* are mobility system performance indicators but also reflect the quality of life in the city.

Opportunity for active mobility is an internal mobility system property, but the improvement of this indicator can clearly contribute to diminishing city transport greenhouse gasses emissions per unit travelled. *Occupancy rate, intermodal connectivity* and *intermodal integration* are the three indicators only referred to as mobility system performance features.

Energy efficiency is commonly regarded as an important indicator of the use of global resources by city transport. But because the parameter also refers to efficiency, the indicator can be classified as an internal mobility system feature too.

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

- **Global environment (G)**
  - Mobility space usage
  - Emissions of greenhouse gases (GHG)
  - Congestion and delays
  - Energy efficiency
  - Opportunity for active mobility
  - Resilience to disaster and ecological/social disruption

- **Economic success (E)**
  - Functional diversity
  - Commuting travel time
  - Economic opportunities
  - Net public finance
  - Mobility space usage

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

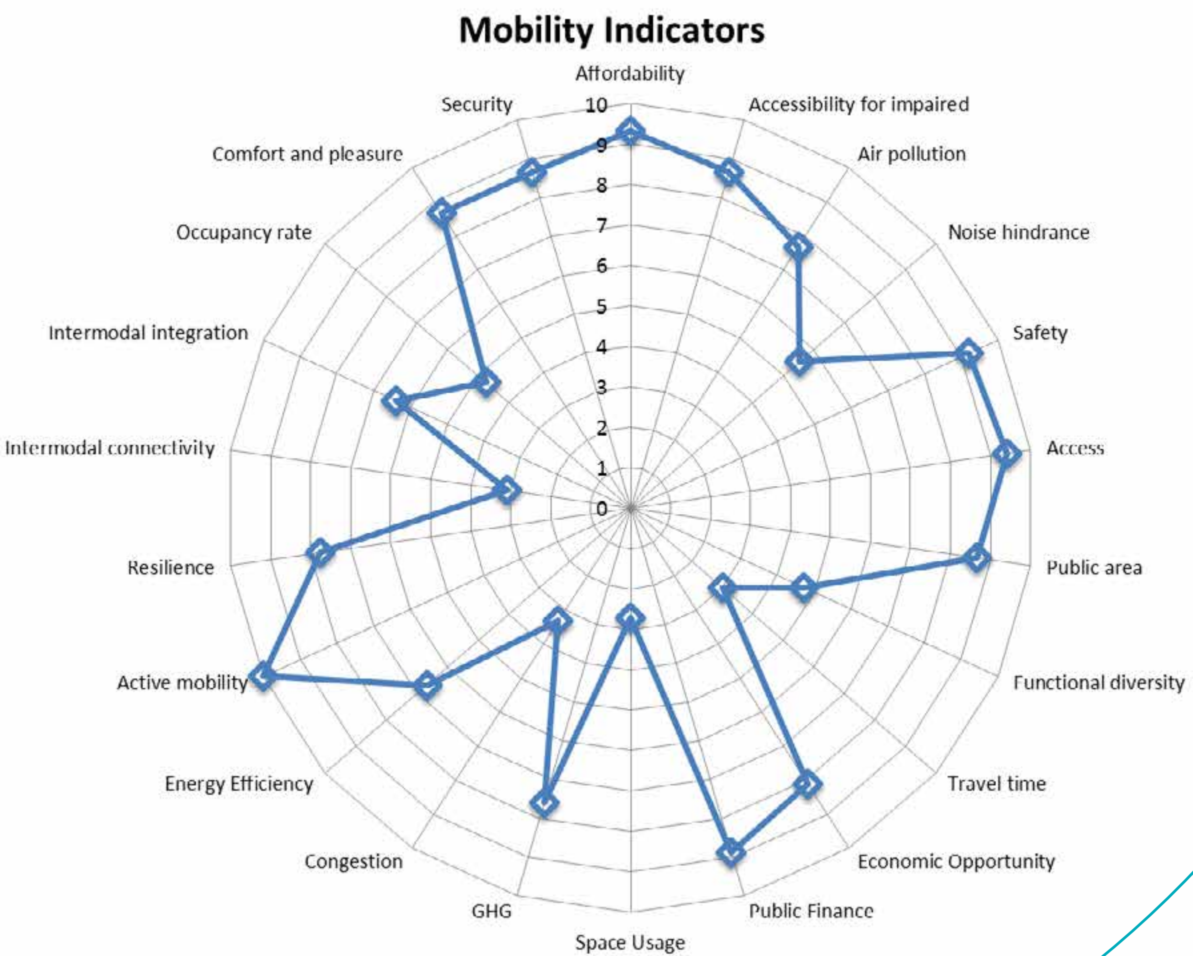
- **Performance of the mobility system (S)**
  - Congestion and delays
  - Energy efficiency
  - Opportunity for active mobility
  - Resilience to disaster and ecological/social disruption
  - Intermodal connectivity
  - Intermodal integration
  - Occupancy rate
  - Comfort and pleasure
  - Security
  - Affordability of public transport for the poorest group
  - Accessibility for mobility-impaired groups

The benefits of working with these 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.

For each of the indicators mentioned in table 1 a parameter is described in chapter 8. The formulae and the description of the input variables to calculate the parameters can be found in that chapter too. The value of the indicators is represented on a scale of 0 to 10 (10 being the best attainable score within the present state of the art of technology).

SMP2.0 proposes to represent the scores for the 22 indicators on a spider chart to give a disaggregated overview of the sustainable mobility performance of the city (Here). As such, strengths and weaknesses can be identified for each mobility indicator. This opens up the possibility to look at cities having the desired strengths in order to identify mobility actions to implement.

Figure 1: Spider chart for 22 Sustainable Urban Mobility Indicators for a fictitious city. Source: Oran Consulting for WBCSD SMP2.0, 2014



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, decreasing congestion is expected to positively impact on GHG, air pollution and travel time.

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 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.

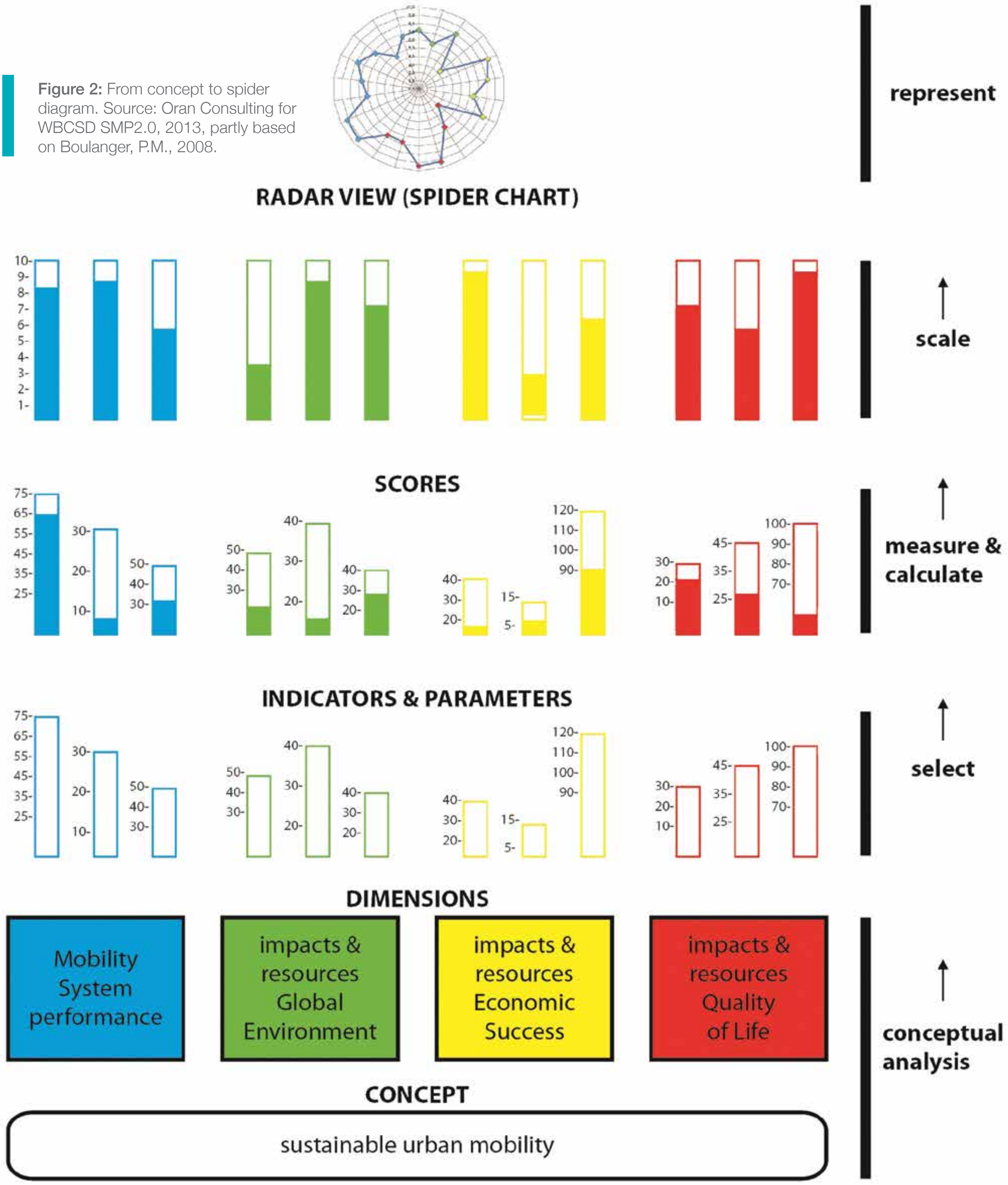
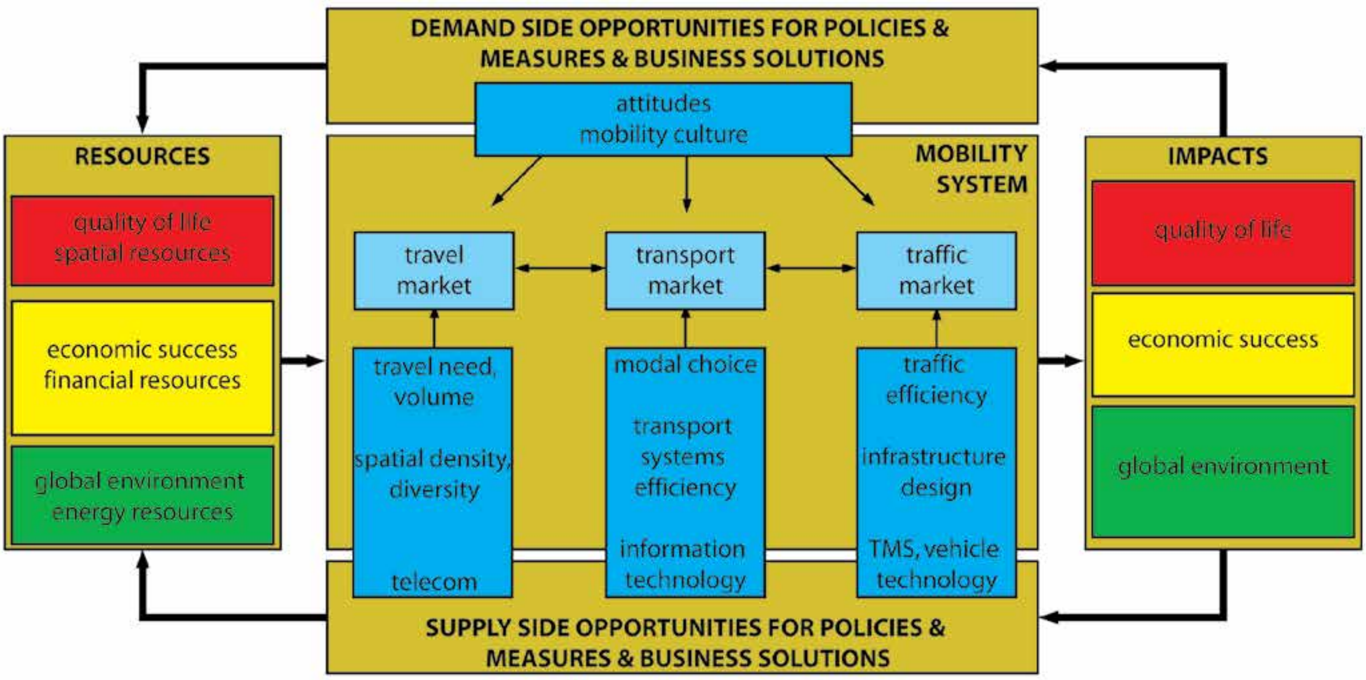


Figure 2: From concept to spider diagram. Source: Oran Consulting for WBCSD SMP2.0, 2013, partly based on Boulanger, P.M., 2008.

V Systems approach and indicator categories

Sustainable mobility indicators come within 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



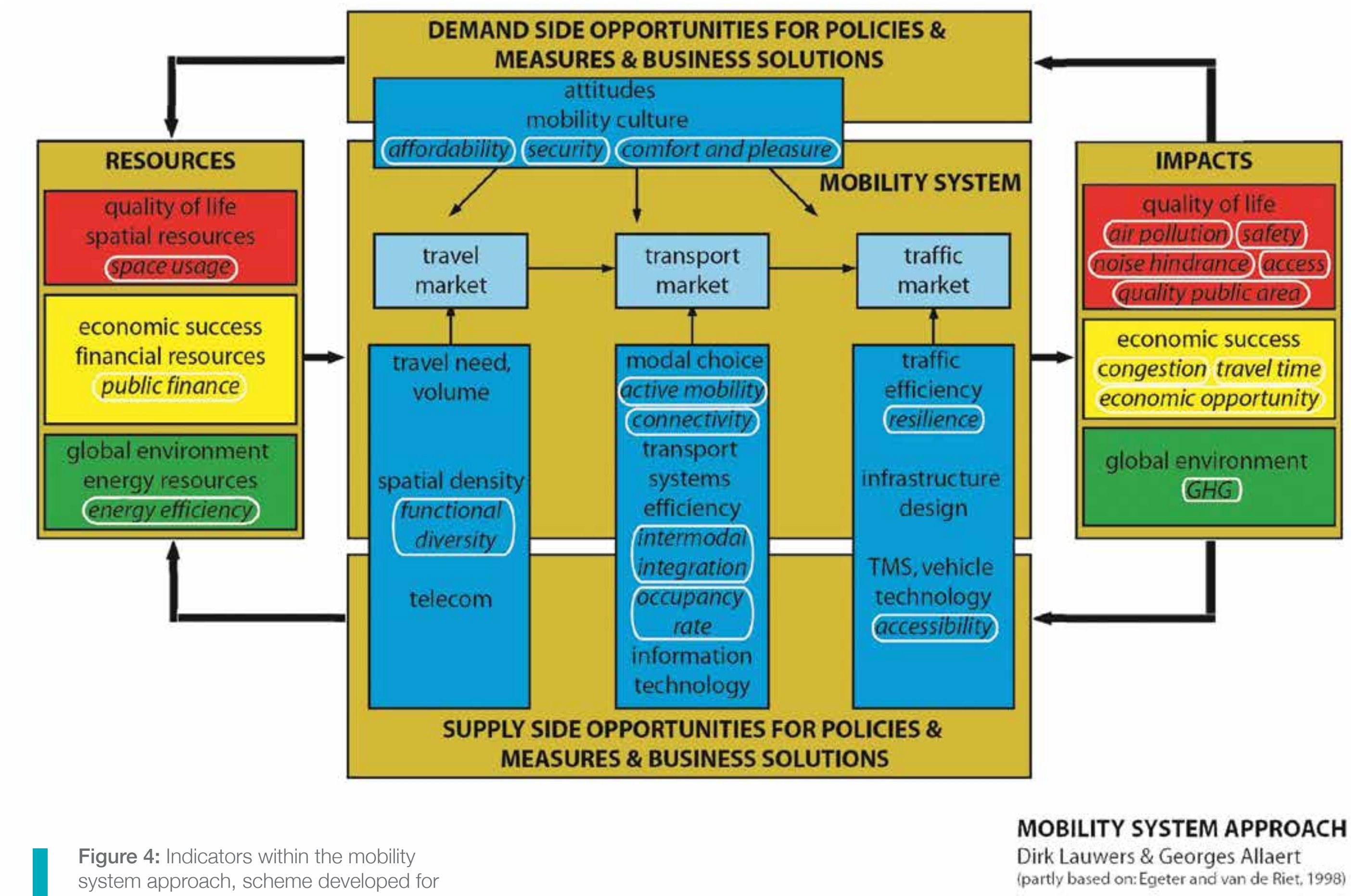


Figure 4: Indicators within the mobility system approach, scheme developed for WBCSD by D. Lauwers and G. Allaert, source oran consulting for WBCSD SMP2.0 IWS, 2014

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. However, 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

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

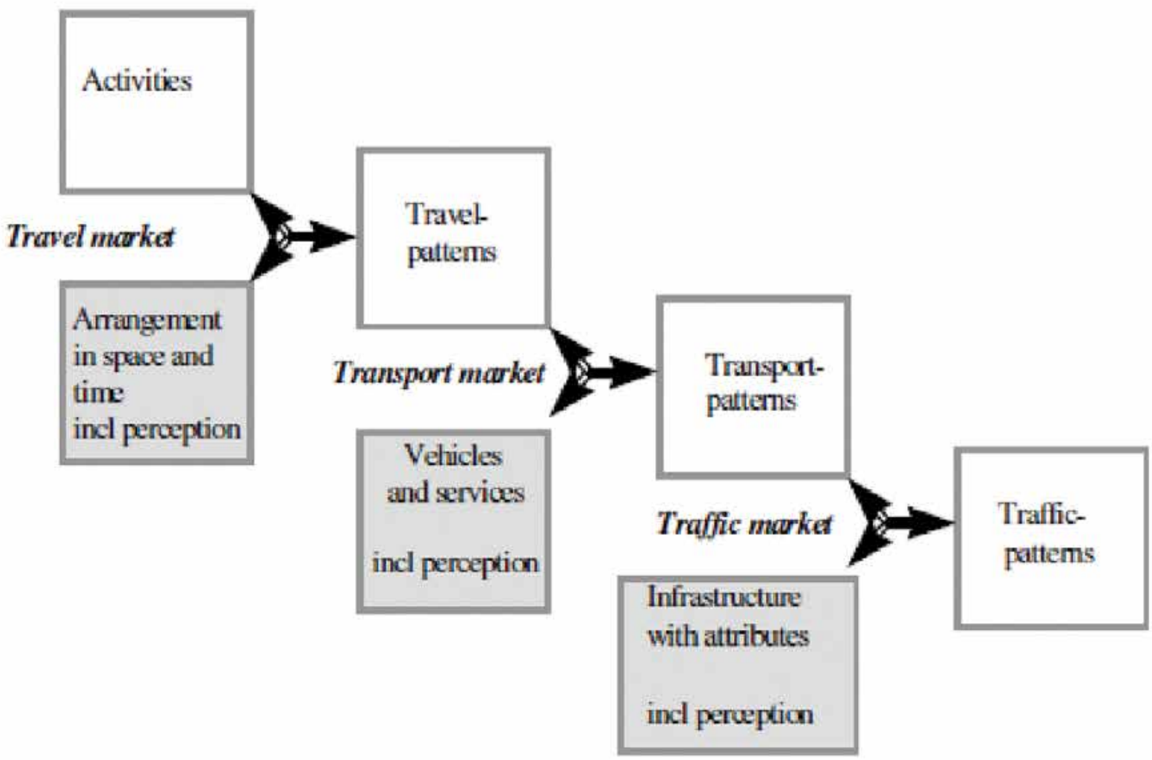
A second category of policies and solutions affects the transport market. This can be obtained by influencing **modal choice**. Although cars will continue to be an essential part of the urban mobility system for the foreseeable future, there are possibilities to increase both the supply and the attractiveness 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.

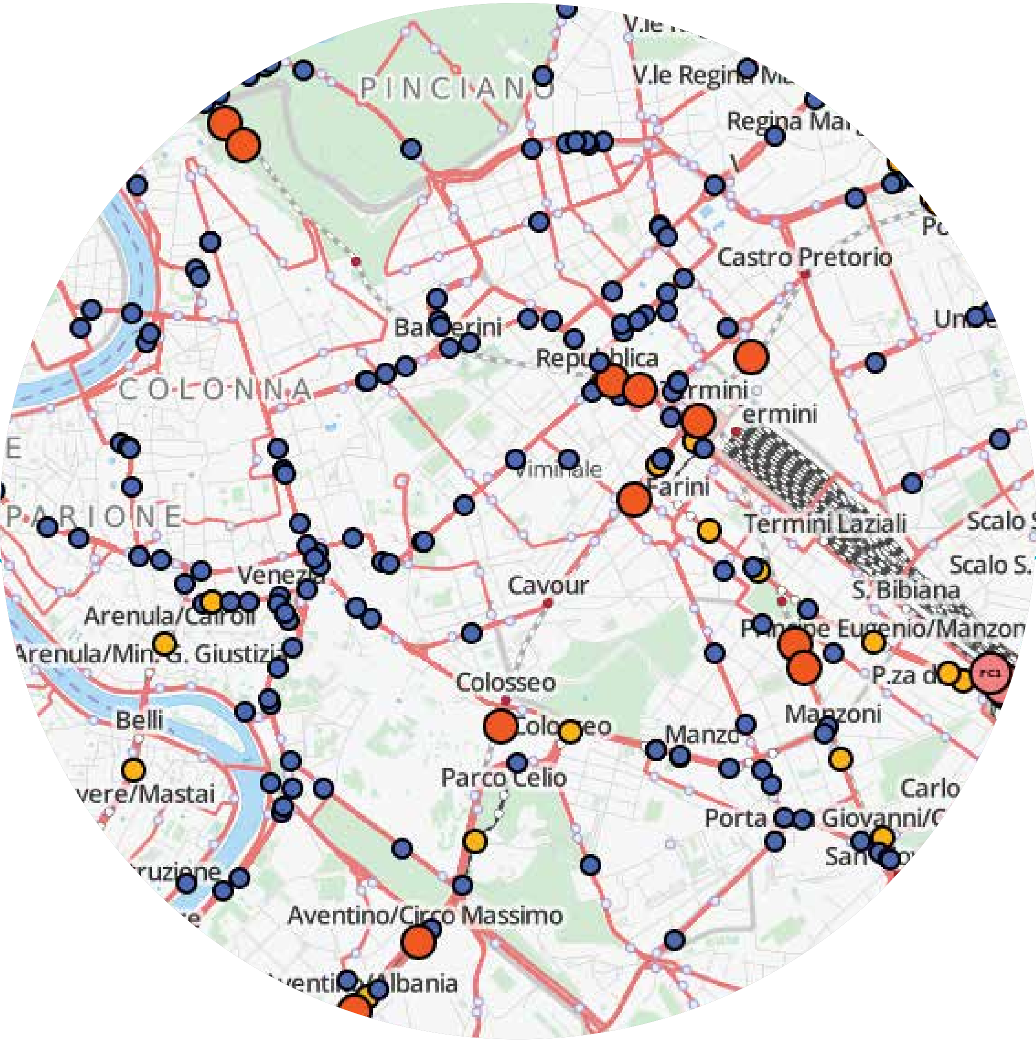
Opportunities for policies and solutions in the traffic market consist of influencing **traffic efficiency**. Traffic efficiency refers to the extent to which the potential capacity of the existing traffic system is exploited. Here, modern traffic management systems (TMS), usually based on telematics 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 22 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.

The score of each of the indicators is represented by an index. The index is defined based on a parameter value representing the performance for the indicator concerned.

Different methodologies can be used to quantify the indicators. One main goal of the present work was to select or design the most appropriate methodology that would be specific, measurable and attainable by the largest number of cities. Sticking to one methodology per indicator through time will allow cities to identify their improvements. And having a common methodology across several cities will enable the building of a valuable source of knowledge to which cities could refer in understanding what best practice in a particular indicator looks like.

The selection process of the indicators and parameters is not described in this report. For those interested, some details of this selection process can be found in additional documents A and B.
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.

2 Scope of the indicators

Air transport (except for helicopters used on urban scale) **and sea shipping are excluded**. In most cities (the sustainability aspects of) these modes are beyond the scope of urban governance.

To avoid that the impact of city size (population, geographical area covered, etc.) on mobility (e.g. total distance travelled) and on input (e.g. total energy use for travel) or output (e.g. total emissions) is reflected in the indicator value, the most **appropriate reference unit** per indicator has to be identified.

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

3 Value and scaling of parameters

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 **calibration** of these scales in this report is provisional as, for most indicators, it is based on only two reference cities (Brussels, or other Belgian cities if input data is available, and Lisbon as a first pilot city for the testing of the methodology). If the parameter is not specific to the WBCSD SMP2.0 and is more commonly used, extreme values (in order to define the 0 and or 10 value) have been searched for in literature. And of course for some parameters extreme scale values are a deductive choice. They can be based on 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). However, the final scaling can be calibrated only based on more (pilot) cities values. So adjustments to the scaling might be appropriate later in the process.

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. So one has to know, for example, what a good or bad score for travel time is and what a good or bad score for public finance is in order to compare the performance for both indicators in the city (the scales will, of course, influence the image provided in the spider chart).

- 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 the parameter values. To do so, the parameter values must be standardized. However, important improvements on a small scale can be lost in the bigger entity. For that purpose, 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** for the whole of the city. So the parameter value is an average 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. This tailor-made evaluation can be used to target specific issues. The database and parameter calculation tool is prepared to be extended with (up to 5) city-specific applications, in addition to the standard methodologies.

VII General Methodology

1 Calculation methodology for the indicator parameters

Chapter VIII 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 in chapter VIII. An Excel-based instrument to calculate the formulae is available, and how to work with it in general is described here, in chapter VII. A detailed description of what to do for each of the parameters can be found in the next chapter. This chapter also defines the different types of variables used in the formulae.

a Types of variables

There are seven types of variables:

1. **Common input variable:** 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 the number of fatalities to calculate the level of transport safety for the indicator describing this aspect of the sustainability of 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. These values are based on assessments by the WBCSD SMP2.0 and its consultant and validated by an international assurance panel. Of course, if cities have more appropriate values available (because of regional differences in, for example, the energy content of a liter of fuel used in the country), the default value can be replaced with a city-specific value.

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

For each of the indicators, a score between 0 and 10 is calculated based on the parameter value obtained via the calculation with the formula used and a scale proposed. To be able to report the result obtained on a scale between 0 and 10, the minimum and maximum values of the parameter have to be related to 0 and 10. In the Excel sheet, an automatic formula allows the city to obtain a score (between 0 and 10) based on the result of the parameter calculation. If a city wishes to narrow down or extend the scale (e.g. to narrow down the span in order to highlight improvements), other minima/maxima values could be assigned to the values 0 and 10.

c Guideline for the Excel calculation

The Excel sheet consists of different worksheets:

- The first sheet – **FRONTPAGE** – gives the title and the color code of the different types of variables and the list of the 22 indicators, including the dimensions they represent.

By clicking on the name of an indicator in the list, a link will make the connection to the specific calculation sheet of that indicator.

For cities that intend to add local indicators in view of local policy priorities or specific situations, a pre-arranged extension to the WBCSD list is provided.

- The second sheet provides a **user guide**. It is structured according to the different worksheets. The user guide is constructed as an interactive tool, allowing the user to jump to the worksheet that is described in a certain guidance or instruction and to reach the specific user guide information when working on a sheet by clicking the "user guide" button.

- On the third sheet, the **summary** of the results of the calculated sustainability scores is represented in a table and spider chart. It gives an overview of the scores (from 0 to 10) for all 22 indicators. The calculated values for each of the indicators are also shown, as well as the units and scale span. The scale span indicates the minimum and maximum indicator values, corresponding to a 0 or 10 score or vice versa, depending on the direction (up or down, also mentioned on the sheet) of the scoring. If cities have added some local indicators they will also appear in the table and spider after unhiding the related rows (28-32). The name of those "local indicators" should be entered once on the FRONTPAGE sheet.

- The fourth sheet contains a table of all 77 **input variables** used to calculate the 22 parameters, with the indicator name, symbol, definition, and what they are used for. This sheet also indicates for which of the variables a common value has to be filled in. The cells where these values have to be typed are marked. Starting from this sheet, links to the other worksheets are provided:
  - o One can jump to each of the indicator sheets by clicking its name.
  - o Where default values can be used, a link with the next sheet default values is provided.
  - o City-specific common values (such as the number of inhabitants) have to be filled in on this page and will be copied automatically to the input cells of the indicators concerned. So the Excel calculation tool allows data that may be used in a number of indicators to be entered only once and therefore to be consistent.

- The fifth sheet – **default values** – contains a table allowing for the adjustment of the minimum and maximum scale values. The default values that are proposed as a common standard and that were used in the example presented are filled in. If a city wishes to adapt the scale range (e.g. to test some solutions in a more sensitive way), it can do so by filling in the respective values in this table.

An energy unit conversion table is also presented on these sheets. These conversion factors are made available automatically on the calculation sheets of the indicators concerned. Some other conversion tables are also shown (from non-metric to metric values, e.g. miles to km). A table allows the user to change from metric units to other standards used in different regions of the world.

- The following sheets each contain the calculation for one of the 22 parameters. Each sheet includes the name of the indicator, the formula and a table to be filled in with the input values. The resulting value of the parameter is also shown. A fixed color code for the different types of variables is used in these sheets (code shown on the front page).

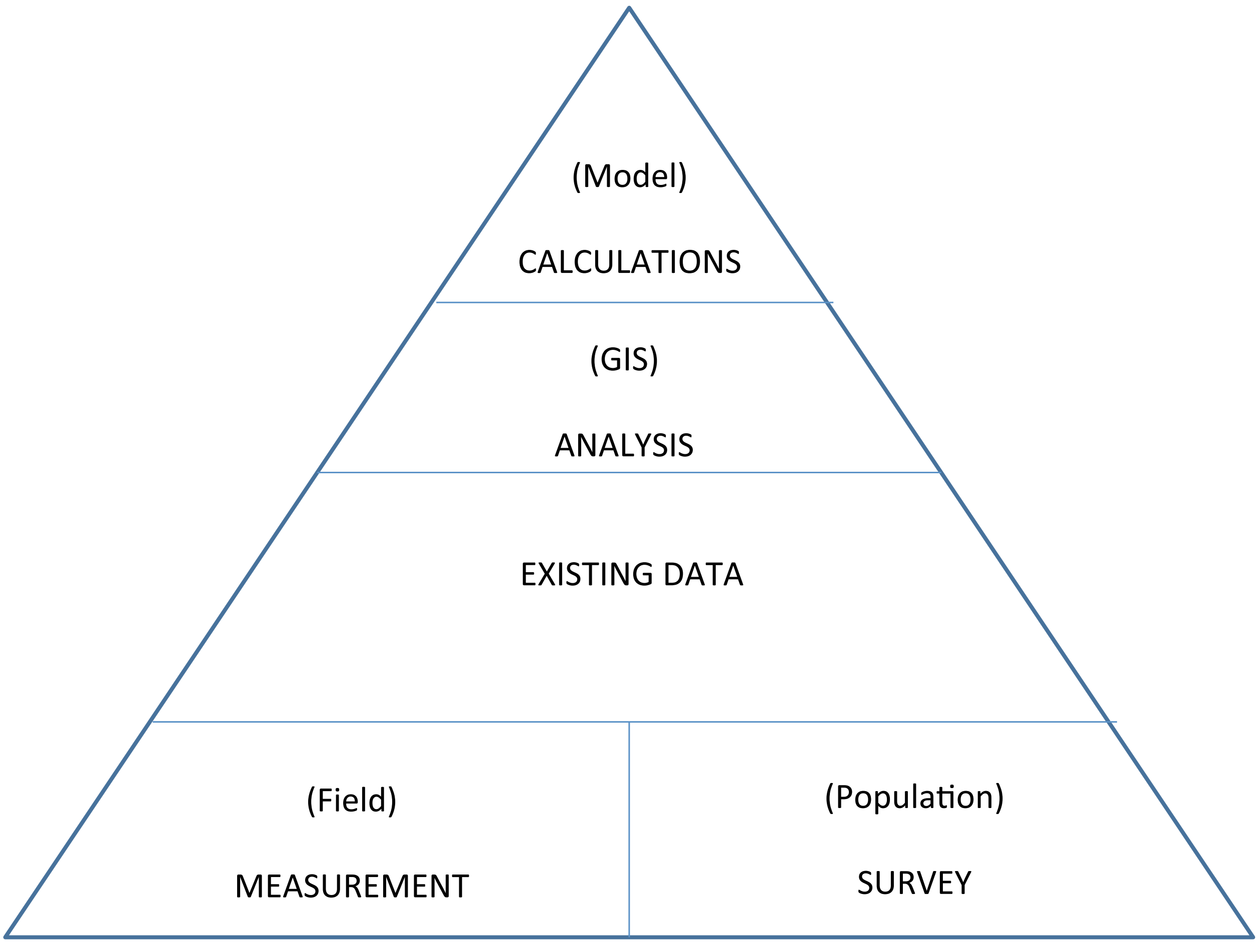
If a city wishes to develop specific approaches (e.g. for specific areas in the city) or approximate values – requiring additional data sets and calculations – the free space on the Excel sheets can be used. Calculations are assumed to be in metric standard units; if a city wishes to work with alternative units instead (e.g. miles instead of km), the city can change this option by choosing a pre-coded unit on the "default values" page.

Four buttons on each indicator sheet offer flexible use of the worksheet, allowing users to jump back to the worksheets that are common to the indicator set. These buttons are:
- "Frontpage" (see first worksheet, described above)
- "Summary" (see second worksheet, described above)
- "Input" (see third worksheet, described above)
- "User Guide" (see fourth worksheet, described above)

More details for each parameter are described in chapter VIII, which deals with the different indicators.

Before the Excel sheet can be filled in, the input data describing the values for the city have to be gathered.

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



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:
IInput 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). However, while some of these data are stored in existing databases and are directly available, 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. Finally, sometimes traffic (simulation) models have to be used to calculate some traffic or transport features (e.g. vehicle-kilometers travelled on certain types of roads).

Within the framework of this report, a somewhat different grouping of data sources can be found in figure 7. The scheme represents the relationship between the input data and the parameters formula (to be used based on the calculation sheet in the annex of this report, allowing automatic calculation if the input data are input in the appropriate cells). 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 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.

Figure 7: Overview of the typology of input data sources. Source: WBCSD SMP2.0, 2014

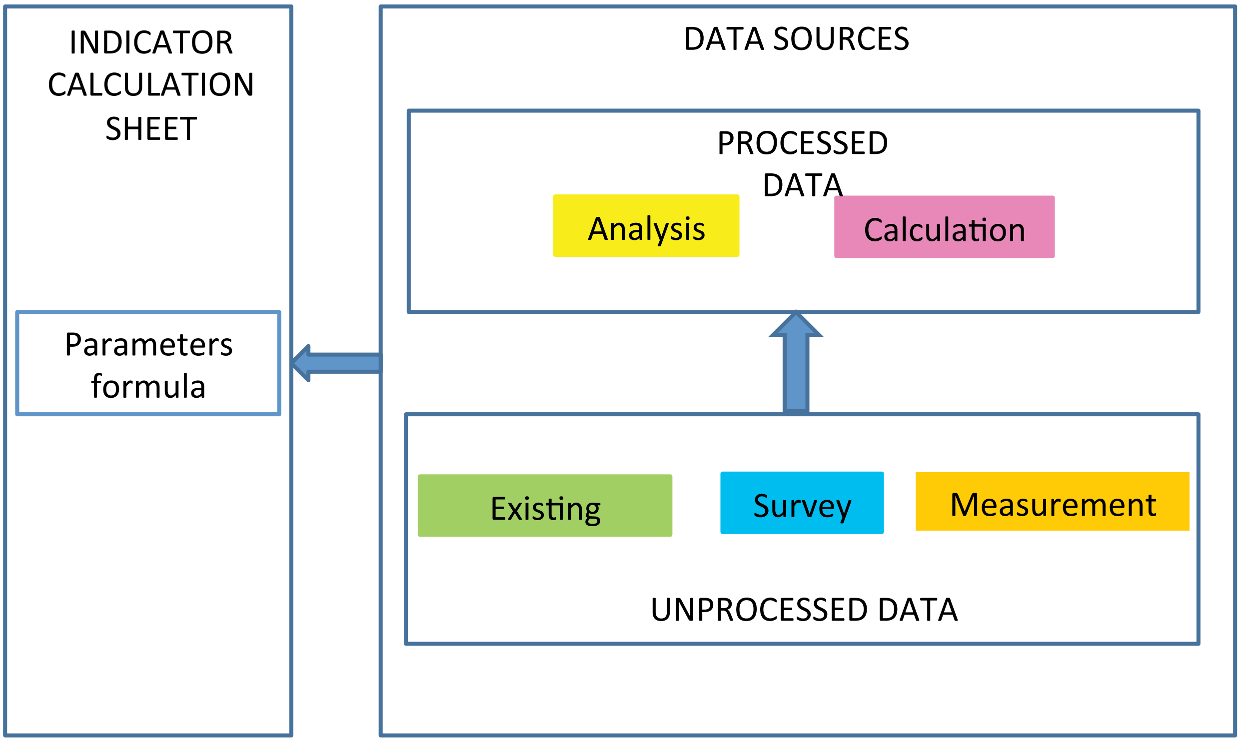
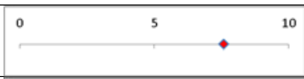
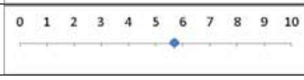
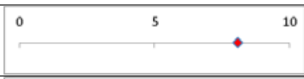
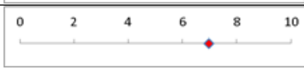
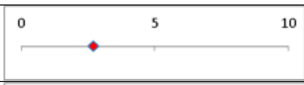
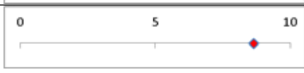
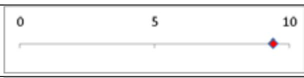
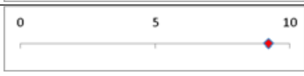
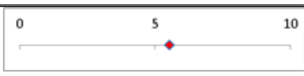
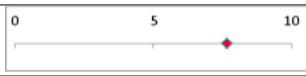
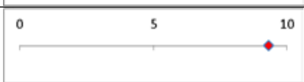
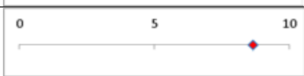
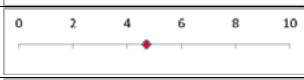
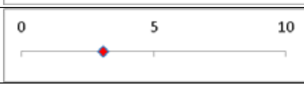


Figure 8 presents an overview of the typology of most appropriate input data sources for all 22 indicators as well as the scaling. However, a more detailed description can be found in the next chapter, which deals with the methodology and scaling of each of the indicators separately. In the following 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 22 indicators, source: WBCSD SMP2.0 IWS, 2014

List of indicators	Input	Scales	
Emissions of greenhouse gases (**GHG**)	Calc.		**0 ≥ 2,75 Ton CO2(eq)/cap.** **10= 0 Ton CO2(eq) /cap.**
Net **public finance**	Exist		**0 = -2,50% GDP** **10 = 0,0% GDP**
Congestion and delays	Measure		**0 = 1,35 % delay during peak hour** **10 =0,0 % delay during peak hour**
Economic opportunity	Exist		**0 = 0% GVAT transport/GDP** **10= ≥ 17,5% GVAT transport/GDP**
Commuting **travel time**	Survey		**0 ≥ 90 minutes/day (av. commute)** **10 ≤ 10 minutes/day(av. commute)**
Mobility **space usage**	Analysis		**0 ≥ 125 m²/cap.** **10 ≤ 25 m²/cap.**
Quality of public area	Survey		**0 = 0% score survey** **10 = 100% score survey**
Access to mobility services	Analysis		**0 = 0% pop. appropriate access to PT or SM** **10= 100% pop. appropriate access to PT or SM**
Traffic **safety**	Exist		**0 ≥ 35 fatalities/100.000 population** **10 = 0 fatalities/100.000 population**
Noise hindrance	Measure		**0 ≥ 75% population hindered** **10 = 0% population hindered**
Air polluting emissions	Calc.		**0 ≥ 75 kg Nox eq./cap** **10 = 0 kg Nox eq./cap**
Comfort and pleasure	Survey		**0 = 0% score survey** **10 = 100% score survey**
Accessibility for mobility impaired groups	Survey		**0 = 0% score survey** **10 = 100% score survey**
Affordability of public transport for the poorest group	Exist		**0 ≥ 35 affordability index PT poorest quartile** **10 ≤ 3,5 affordability index PT poorest quartile**
Security	Survey		**0 = 0% score survey** **10 =100% score survey**
Functional diversity	Analysis		**0 = 0% functional diversity score** **10 = 100% functional diversity score**
Intermodal connectivity	Analysis		**0 = intermodal flex. index 0** **10 ≥ 7 intermodal flex. index**
Intermodal integration	Survey		**0 = 0% score survey** **10 =100% score survey**
Resilience for disaster and ecologic /social disruptions	Analysis		**0 ≥ 18 hours critical evacuation time** **10 ≤ 1 hour critical evacuation time**
Occupancy rate	Calc.		**0 ≤ 10% occupancy rate** **10 ≥ 70% occupancy rate**
Opportunity for **active mobility**	Analysis		**0 = 0 % road length facilities biking +walking** **10 ≥ 200 % road length facilities biking +walk**
Energy efficiency	Calc.		**0 ≥ 3,5 MJ/transport unit km** **10 ≤0,5 MJ/transport unit km**

a Using existing databases

Coefficients have to be found in existing databases for some of the indicators. Some cases concern physical relations between variables and for which the most 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 external databases:

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

Other indicators are completely (or mainly) based on city (or regional-specific) databases that are expected to be available because they have to be reported in the frame of monitoring the more general (apart from mobility) performances of cities, regions or national economies. It concerns:

Net public finance
Economic opportunity
Traffic safety (city or regional/national database)
Affordability of public transport for the poorest group

So the data for these four above-mentioned indicators for the city are grouped in and rely on a first main category referred to further on as "existing data" methodology (M1).

To avoid that city size (population, geographical area covered, etc.) and the impact of city size on mobility (e.g. total distance travelled) and on some input (e.g. total energy use for travel) or output (e.g. total emissions) is reflected in the indicator, the most appropriate reference unit per indicator has to be identified. The number of inhabitants, surface of the city (region), and distance travelled are also specific data that are used as a denominator in the formula. So for all indicators, these reference data have to be searched for in existing databases (e.g. in the yearly reports of public transport companies the passenger kilometers travelled are often reported).

Some indicators need specific data (e.g. on density, demography) in the city. It concerns:

Congestion and delays
Noise exposure (city: densities)
Access to mobility services

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

So the use of existing databases is inherent on all methodologies. Only the second group mentioned in this paragraph (with the four indicators *net public finance, economic opportunity, traffic safety and affordability of public transport for the poorest population)* relies completely on it and is categorized as "existing database" methodology.

b Surveying

A population survey is proposed for the following indicators:

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

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

If for the indicators below 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":

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

Topics to be covered in the surveys are described per parameter (see later). A proposal for a survey form for each of the above-mentioned indicators is described in annex D to this report.

Some general common aspects of the methodology are described here.

Grading and weighting

For the grading of the indicator, a scale should be offered allowing each question to be answered as a score from 1 to 5, where 1 is the lowest grade and the 5 is the highest one (meaning that person is most satisfied). If the interviewee has no opinion or if this question does not apply to him/her, the respective scores of 0 and 99 are given. More difference on the scaling of these individual survey questions makes answering more complex. The answers to the questions are totaled per item to obtain the total score. These totals per item are not simply based on summing up the scores of the different respondents: each of the respondents can, apart from giving his/her appreciation on a certain item (e.g. on the quality of the route information at public transport stops), also give a weight of personal importance of the item. He/she can give the item a score of 0 (not relevant or not applicable), of 1 (of importance) or of 2 (most important item). For each item, a weighted total score is calculated for every interviewee over every question that received a grade of 1 to 5 and a weight of 1 or 2.

The total score (over all interviewees) for the parameter is recalculated on a scale of 0 to 10 (in line with the indicator score scaling).

Target groups

Most topics apply to the total population (in a broad sense: not only inhabitants but also commuters, visitors, tourists, etc.):

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

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.

Defining the size of the sample that represents 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 the less confidence that the survey's 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 confidence level ***c***.

E can be defined as:

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

Table 2 shows the sample sizes based on population size.

Margine 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 408,219 PT users.Based on previously defined values of E, r, and c and suggested formula for determining simple 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

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.

The target group must be representative of the whole population in terms of random selection:
- Gender
- Age groups
- 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.

Survey questions

- Each survey should contain a common part including relevant demographic data and information for verification.

- 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: some questions refer to car sharing. In this report, car sharing refers organized short-term car rental that can be offered by private commercial firms, non-profit organizations or self-organized groups. This type of services is deployed in thousands of cities in different parts of the world and can be referred to. Car sharing is not the same thing as carpooling (the difference might not be obvious for a lot of people) where one driver brings along other people, dropping them off along the way or close to the driver's own destination.

- 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.

- Prior to conducting the survey, all relevant local regulations should be considered (e.g. regulations regarding privacy issues) and surveys adjusted accordingly.

- Questionnaire forms are added to this rapport (see annex D). The Excel calculation tool is pre-formatted to insert the answers of the interviews directly, and based on that to calculate the indicator score automatically. However, a city can adapt the survey questions (but in that case should adapt the Excel calculations 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.

Example of the surveys common part (demographic data):

What is your gender?
What is your age?
What is the highest level of education you have completed?
Which is your profession?
What is the average monthly income of your household?
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.

c Traffic Modelling

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

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

The data for the four 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 databases, 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

Suggested methodology does not imply usage of any 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:

Resilience to disaster and ecological/social disruptions
Congestion and delays
Mobility space usage
Access to mobility services
Intermodal connectivity
Functional diversity
Opportunity for active mobility

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

For some of the indicators, the spatial data needed are rather limited; if no GIS is available they can be collected rather easily.
It concerns:

Resilience to disaster and ecological/social disruptions
Congestion and delays
Intermodal connectivity

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 sources are digital and analogue datasets 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 survey

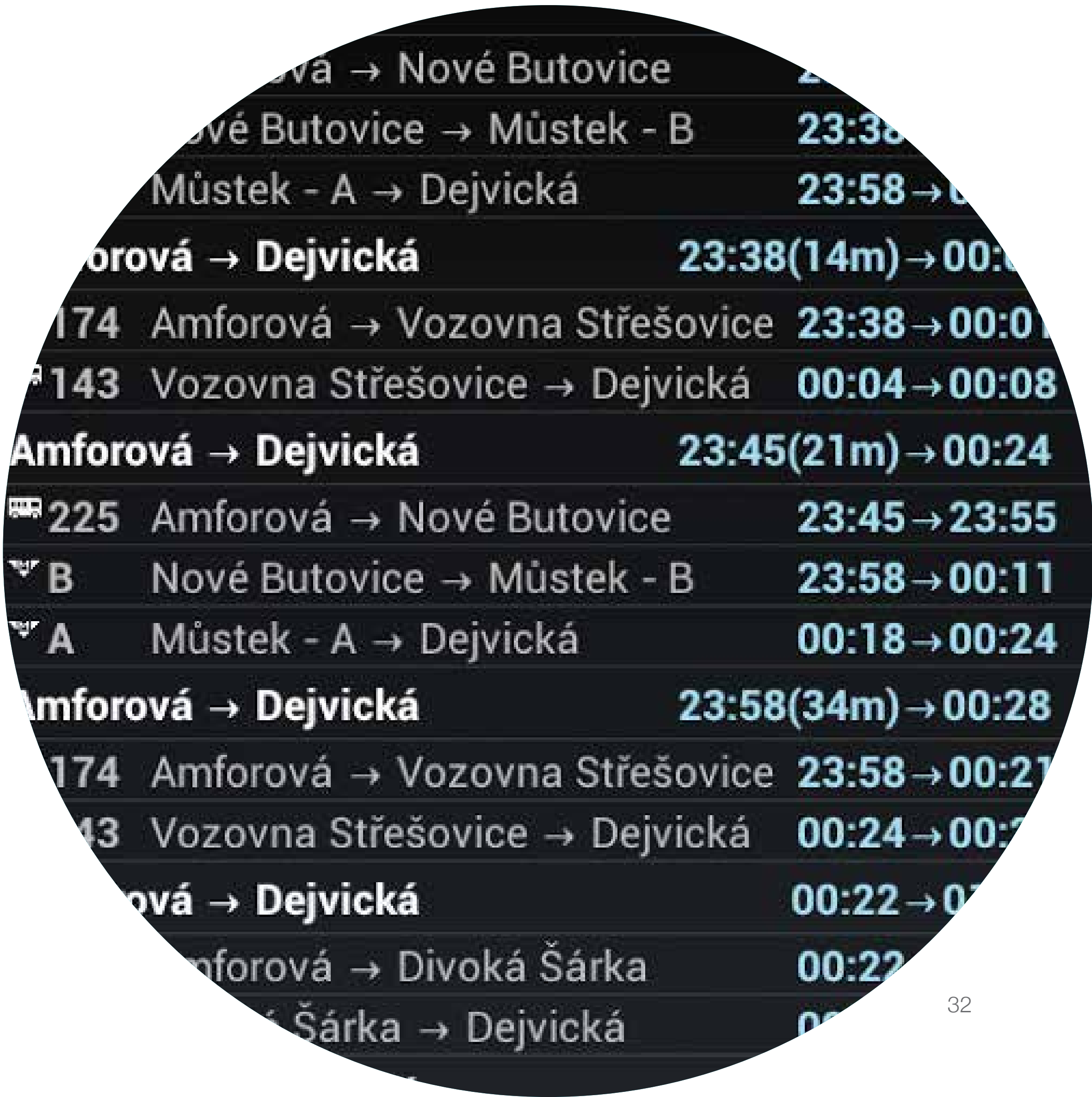
Field survey methodology is limited to:

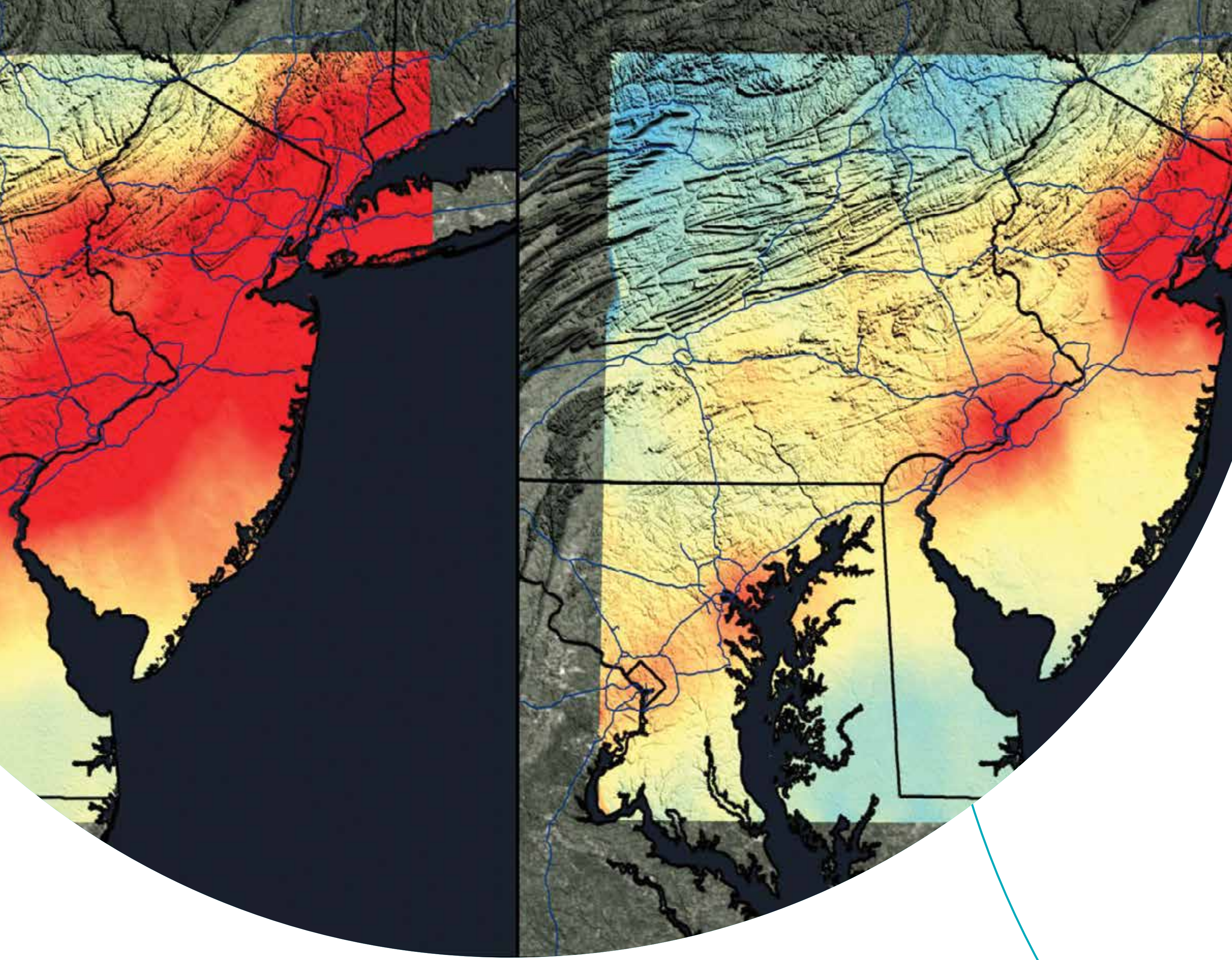
Noise hindrance (with sound level meters at selected locations)

Congestion and delays can also be partly based on field surveys (with a floating car methodology at selected corridors during peak hours). Public transport delays, however, may be obtained as raw data from public transport companies. For road traffic, a less time and cost consuming way is to rely on the data obtained through online requests by route planners (apps) based on real-time traffic conditions for the corridors to be studied, resulting in travel times during peak confronted with travel times in off peak conditions. For this indicator, an alternative method is preferable in most situations.

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).





VIII Methodology for the 22 WBCSD-SMP2.0 Indicators

Emissions of greenhouse gases (GHG)

a Definition
Emissions of greenhouse gases (GHG) by all city passenger and freight transport modes considering well-to-wheels

b Parameter
Tonne CO_2 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 greenhouse gases 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 greenhouse gases.

The total number of vehicle-kilometers is preferably collected by means of a traffic model. Alternative methods are field surveys (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.

Indicator 1 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 CO_2 emissions are calculated. For other greenhouse gases, the CO_2 equivalent emissions are calculated based on the conversion factor per emission unit.

d Formula & calculation method

The total amount city transport greenhouse gases by 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 greenhouse gases;
- **STEP 2:** converting the emissions of the different greenhouse gases into CO2 equivalents;
- **STEP 3:** converting tailpipe emissions (pump-to-wheel) into well-to-wheel emissions.

This is expressed in the following formula:

This is expressed in the following formula:

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

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

$\mathbf{C_k}$ = Tank to wheel CO2 emission per energy type unit considered [kg/l or kg/kWh]

$\mathbf{W_k}$ = Well to tank CO2 equivalent emission per energy type unit considered [factor]

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

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

$\mathbf{I_{jk}}$ = 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 [#]

$\mathbf{F_{ijk}}$ = 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

Preferably, specific national values are used for the conversion factors in order to make calculations specific to the city in case. 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}, I_{jk} and F_{ijk}.

Factors Ck are 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]1.4×10^{-5}	1	1	1	1
Methane[c]	CH_4	12[c]	3.7×10^{-4}	21	72	25	7.6
Nitrous oxide	N_2O	114	3.03×10^{-3}	310	289	298	153
Substances controlled by the Montreal Protocol							
CFC-11	CCl_3F	45	0.25	3,800	6,730	4,750	1,620
CFC-12	CCl_2F_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_2FCClF_2	85	0.3	4,800	6,540	6,130	2,700
CFC-114	$CClF_2CClF_2$	300	0.31		8,040	10,000	8,730
CFC-115	$CClF_2CF_3$	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	$CBrF_2CBrF_2$	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_3Br	0.7	0.01		17	5	1
Methyl chloroform	CH_3CCl_3	5	0.06		506	146	45
HCFC-22	$CHClF_2$	12	0.2	1,500	5,160	1,810	549
HCFC-123	$CHCl_2CF_3$	1.3	0.14	90	273	77	24
HCFC-124	$CHClFCF_3$	5.8	0.22	470	2,070	609	185
HCFC-141b	CH_3CCl_2F	9.3	0.14		2,250	725	220
HCFC-142b	CH_3CClF_2	17.9	0.2	1,800	5,490	2,310	705
HCFC-225ca	$CHCl_2CF_2CF_3$	1.9	0.2		429	122	37
HCFC-225cb	$CHClFCF_2CClF_2$	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_2F_2	4.9	0.11	650	2,330	675	205
HFC-125	CHF_2CF_3	29	0.23	2,800	6,350	3,500	1,100
HFC-134a	CH_2FCF_3	14	0.16	1,300	3,830	1,430	435
HFC-143a	CH_3CF_3	52	0.13	3,800	5,890	4,470	1,590
HFC-152a	CH_3CHF_2	1.4	0.09	140	437	124	38
HFC-227ea	CF_3CHFCF_3	34.2	0.26	2,900	5,310	3,220	1,040
HFC-236fa	$CF_3CH_2CF_3$	240	0.28	6,300	8,100	9,810	7,660
HFC-245fa	$CHF_2CH_2CF_3$	7.6	0.28		3,380	1030	314
HFC-365mfc	$CH_3CF_2CH_2CF_3$	8.6	0.21		2,520	794	241
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	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_2F_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

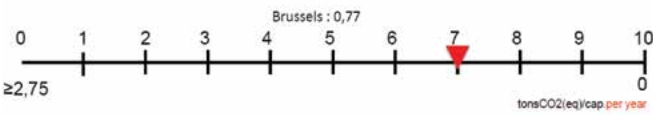
Fuel	Feedstock	WTP	PTW	WTW
		gCO$_2$e/mi		
Gasoline	U.S. Average	93	358	451
Ethanol (E85)	Corn	19	352	371
	Switchgrass	-233	352	119
CNG	NA NG: U.S. Average	119	272	391
LNG	NA NG: U.S. Average	118	273	391
Hydrogen	Central NG SMR	238	0	238
	Electrolysis, Renewables	3	0	3
Electricity	U.S. Mix	333	0	333
	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.

)utput: Lifecycle impacts of each fuel by grams of CO_2 per mile (gCO_2e/mi) as

- *"well to pump (WTP)," – emissions to extract, produce, and transport*
- *"pump to wheel (PTW)," – tailpipe emissions; and*

f Scale



The indicator is scaled using the following graph:

➔ 0: ≥2.75 tonnes $CO_{2(eq.)}$/cap.
➔ 10: 0 a.t. tonnes $CO_{2(eq)}$/cap.

g Calculation sheet

As for the sheets for *energy efficiency* and *air pollution* the calculation sheet for this indicator contains different energy intensity factors (kg, kWh or l per km) for different energy products -called "fuel types" in the sheet – used for urban transport. (gasoline, diesel, CNG, LPG, heavy oil, ethanol, bio-ethanol, bio–diesel, hydrogen, electricity, coal). "Hybrid" is also mentioned in this column; cities have to identify if this category is relevant in the local context and if so what combination of "fuel types" have to be used. The energy products mentioned are also repeated in the calculation of energy consumption for the different modes. The vehicle-kilometers driven in the city by these modes have to be put in the calculation sheet in the appropriate cells. This information can be based on traffic modelling or other sources mentioned. In the sheet, there is also a column to put in the shares of the different fuel types (S_{jk}) for each mode; these shares have to be found in national databases if the city has no specific dataset on this breakdown.

h Notes

- A comprehensive approach is provided, including well to wheel emissions. By doing so, the total CO_2 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 (see above) available in the transport market, resulting in fewer km driven for travel with same origin-destination.

- Gases other than CO_2 are included in the parameter using equivalent coefficients expressing the global-warming potential (GWP) relative to the GWP of CO_2.

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 finances 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]

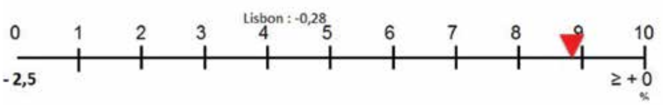
O_j = City government annual operational costs related to city transport (all modes) [currency per year]

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

e Source

Parameter developed for WBCSD SMP2.0.
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 Calculation sheet

The calculation sheet contains input cells for C_i, O_j and GDP. It is recommended to input GDP in the INPUT sheet as from where it is copied automatically to this and other indicator sheets.
The indicator value is calculated automatically.

h Notes

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

- Costs are limited to OPEX; CAPEX 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.

Congestion and delays

a Definition

Congestion in road traffic and delays in public transport deviation (extra time needed to drive or travel) from free-flowing for all transport modes during peak hours

b Parameter

Weighted average per trip of the ratio of peak period travel times to free-flowing travel times in road traffic and travel time adherence of public transport during peak hours on up to 10 major corridors of both transport modes

c Methodology description

➔ M5: Measurement (field survey) (and M1: Analysis and external raw data)
Congestion and delays in city transport can be partly based on a field survey (with floating car methodology at selected corridors during peak hours); public transport delays, however, may be obtained as raw data from public transport companies. For road traffic, a less time- and cost-consuming way is to rely on the data obtained by online requests of route planners (apps) based on real-time traffic conditions for the corridors to be studied, resulting in travel times during peak hours versus travel times in off-peak conditions.

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) is opposed to the travel time in these corridors under free flow conditions.

The floating car method is proposed. This method requires a driver and a passenger to be in the vehicle. The driver operates the vehicle while the passenger records time information at predefined checkpoints.

Three levels of instrumentation are used to measure travel time with a floating car:

- Manual - manually recording elapsed time at predefined checkpoints;

- Distance measuring instrument (DMI) – determining travel time along a corridor based upon speed and distance information provided by an electronic DMI connected to the transmission of the test vehicle;

- Global navigation satellite system (GNSS) – determines test vehicle position and speed by using signals from the system of Earth-orbiting satellites.

Since the driver of the test vehicle is a member of the data collection team, driving styles and behavior can be controlled to match desired driving behavior. A floating car driver “floats” with the traffic by attempting to safely pass as many vehicles as pass the test vehicle. In practice, however, drivers will likely adopt a hybrid of the floating car and average car driving style (test vehicle travels according to the driver’s judgment of the average speed of the traffic stream) because of the inherent difficulties of keeping track of passed and passing vehicles in high traffic volume conditions.

Sample Sizes

Sample size requirements for the floating car technique dictate the number of “runs” that must be performed for a given roadway during the time period(s) of interest. The use of minimum samples sizes, or a minimum number of travel time runs, ensures that the average travel time obtained from the floating car is within a specified error range of the true average travel time for the entire vehicle population.

To compute sample sizes for floating car travel time runs, a formula derived from standard sample size equation is given:

$$Sample\ Size,\ n = \left(\frac{t \times s}{\varepsilon}\right)^2 = \left(\frac{t \times (c.v. \times \bar{x})}{(e \times \bar{x})}\right)^2 = \left(\frac{t \times c.v.}{e}\right)^2$$

where:
t = t-statistic from student’s t distribution for specified confidence level;
s = standard deviation of travel time; and
Ɛ = maximum specified allowable error
$\bar{x}$ = mean travel time
c.v. - coefficient of variation

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.

d Formula & calculation method

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

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]

FFT_i = 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]

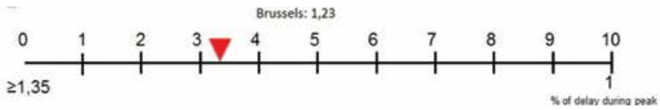
MS_{road} = Modal share road [%]

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

e Source

Floating car measurement method for car traffic, transit delay statistics for public transport.

f Scale



➔ 0: >1.35 relation peak hour time/normal condition travel time = % delay
➔ 10: 1 relation peak hour time/normal condition travel time = % delay

g Calculation sheet

The calculation sheet contains prepared input cells for the input variables mentioned above (see d. Formula & calculation method) for 10 road and 10 public transport corridors. The indicator value is calculated automatically.

h Notes

- The expression in percentage deviation from normal traffic and transport conditions is to avoid reflecting the city size and to validate all relevant transport measures, independent of the technology used.

- Normal road traffic conditions are defined as the free flow condition; for public transport it refers to the scheduled running times (if timetables do not exist, e.g. for paratransit, reference is made to travel times in normal road traffic conditions).

- The indicator reflects peak hour conditions (definition of peak hour: period at the beginning and end of the working day when large numbers of people are travelling to or from work, so the city has to identify this period referring to local conditions) on 10 major road and 10 major public transit corridors in the city.

- A methodology for peak hour conditions on a selection of 10 corridors is proposed; however, for cities where more elaborated measurements are available, such as the INRIX index for roads, this index is preferred for the road part in the indicator.

Economic opportunity

a Definition
Direct economic sectorial contribution to the welfare of the metropolitan area from city transport

b Parameter
Share of GVA (gross value added) by city transport sector and storage

c Methodology description
➔ M1: Raw data (existing database)
To classify the economic opportunity added by city transport the share of GDP added by transport and storage is calculated for each city. Analogous to the World Bank and the OECD, this is based on the existing data divided according to the International Standard Industry Classification (ISIC).

d Formula & calculation method

$$EO = \frac{100 * GVAT}{GDP}$$

EO = Economic opportunity of city transport [%]

GVAT = Contribution gross value added by transport and storage sectors [currency per year]

GDP = Total gross domestic product city (region) [currency per year]

c Source
The proposed sources are the incomes according to the ISIC (also used by the World Bank and the OECD). http://unstats.un.org/unsd/publication/seriesM/seriesm_4rev4e.pdf:

Section F: Construction
Division 42 Civil engineering
4210 Construction of roads and railways
421 4210 Construction of roads and railways
Section G: Wholesale and retail trade; repair of motor vehicles and motorcycles
Division 46 Wholesale trade, except of motor vehicles and motorcycles
Section H: Transportation and storage
Section N: Administrative and support service activities
Division 77 Rental and leasing activities
771 7710 Renting and leasing of motor vehicles

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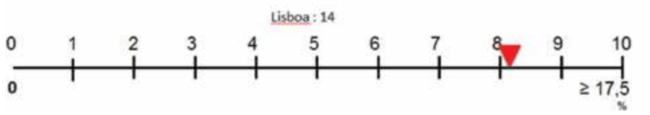
771 7710 Renting and leasing of motor vehicles

f Scale


➔ % GDP
➔ 0: 0
➔ 10: > 17,5 %

g Calculation sheet
The calculation sheet contains prepared input cells for GVAT and GDP. GDP can be put in on the INPUT sheet and is copied automatically to the indicator sheet. The indicator value is calculated automatically.

h Notes
- The transport sector is one of the key factors of economic and social urban development, both in terms of revenues in the added economic value as well as in the need for mobility.
- Job creation is also accounted for in this indicator.
- As storage of goods and transport of goods are both integral parts of the logistic chain, both sectors are considered as one unit; manufacturing is excluded.
- Apart from the direct economic sectorial contribution to welfare, the mobility of persons and the transport of goods are conditional for economic production in all economic sectors; this indirect contribution is not covered by the indicator.

Commuting travel time

a Definition
Duration of commute (travel to work or to an educational establishment)

b Parameter
Average time of commute (travel to work or to an educational establishment and back home) in the city expressed in minutes per person per day

c Methodology description
➔ M2: Survey
The outline of the “Survey methodology” is described in the general part. A proposal for a survey form is attached in annex E. The target population is commuters.
- 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 of

the city or external commuter.
- Questions refer to modal choice and travel time: The average time to commute (travel to work or to an educational establishment, average between outward journey and return journey) is expressed in minutes per day. It enables comparability between cities since only commuting trips are considered.

d Formula & calculation method
The variable is the average weighted survey score.

$$Tcom_{av} = \frac{\sum_i (Tcom_i)}{\sum Fi}$$

With :

$$T_{com_i} = F_i * (T_{out_i} + T_{return_i})$$

Tcom$_{av}$ = Average commuting time [minutes/day]

Tcom$_i$ = Commuting time surveyed person i [minutes/day]

F$_i$ = Weight factor person I (number of trips/week) [#]

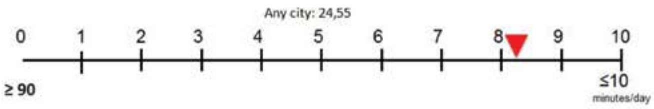
For **F**$_i$ either the weekly frequency of trips to school or to work has to be taken into account (maximum of both, maximum value = 5) [#]

Tout$_i$ = Average commuting time home to work/school [minutes/day]

Treturn$_i$ = Average commuting time back from to work/school to home [minutes/day]
i = Number of persons in survey [#]

i = Number of persons in survey[#]

e Source
Proposed methodology is based on: 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 Calculation sheet
The calculation sheet contains 400 prepared input cells for the indicator. In each of these cells, the average score of an interview can be filled in. The average score is calculated automatically. If more surveys have been done, the input column can be extended, but the calculation of the final score has to be adapted for the indicator.

h Notes
- Though commuting does not cover all travel in cities, limiting the definition to this travel motive has the advantage that these travel patterns are best documented and sharply defined.

- Commuting refers to basic activities and travel that are essential for social and economic development. In the frame of this report, the decision was made to focus on commuting travel time to work or educational places because they are the most important trips for people and often the most inflexible ones.

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 [#]

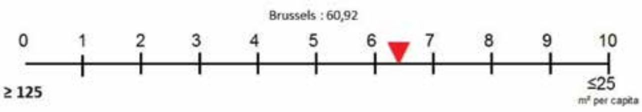
Efficiency refers indirectly to mobility output by referencing total population
Direct land use by city transport refers to the area covered by transport infrastructure such as roads

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 on-street and off-street parking areas, security areas, service areas, stations, inland port hubs, storage areas and distributions centers for city freight transport.

e Source
Described methodology is based on information from the Victoria Transport Policy Institute.

f Scale



➔ 0: ≥ 125 (m^2/capita)
➔ 10: ≤25 (m^2/capita)

Some reference values: average artificial land take circa 400m^2/capita in EU (2006) . Land use for car traffic is almost the same amount as for housing (US; source: Litman). A maximum score of 125 m^2 is therefore reasonable.

g Calculation sheet
The calculation sheet contains prepared input cells for indirect and direct land use.

DIRECT
Fast transit roads
Other roads
Railways
Inland ports and water ways

INDIRECT
Open parking
Private parking
Service area and petrol stations
Storage and logistics centers
Stations

The total land use is calculated automatically. If more land use categories are distinguished, extra input cells can be organized, but the calculation of the final score has to be adapted for the indicator.

h Notes
- Direct land use by city transport refers to the area covered by transport infrastructure such as roads and streets and squares used for moving people on and off of vehicles (public areas excluding parks, playgrounds and sports fields). Airports and seaports are excluded, inland ports are included.

- Indirect land use by city transport refers to indirect uses, in particular: on street and off street parking areas, security areas, service areas, stations, inland port hubs, storage areas and distributions centers for city freight transport.

- 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).

- 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 of parking and service areas.

Quality of public area

a Definition
Quality of public area, presence in the city of streets and squares that offer sociability and a good image

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 attached in annex E. The target population is the users and non-users of public spaces.
- 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.

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

As with the other surveys, interviewees are asked to give an importance factor (0, 1, 2) and a score from 1 (most unsatisfied) to 5 (most satisfied) for each question.

d Formula & calculation method
The variable is the average survey score.

$$PAsc_{av} = \frac{\sum_i (PAsc_i)}{i}$$

$$PA_{sci} = \frac{\sum_{j=1}^{m} Q_j * W_j}{\sum_{j=1}^{m} W_j}$$

$PAsc_{av}$ = Average score public area quality appreciation and sociability [%]

$PAsc_i$ = Weighted score for public area quality appreciation and sociability for surveyed person i [%]

i = Number of persons in survey [#]

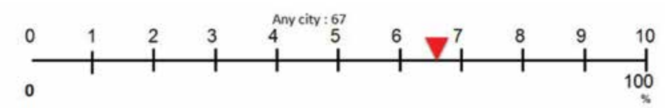
Qj: Score on the quality questions [#]

Wj: Score on the importance questions [#]

m = Number of topics handled [#]

e Source
Proposed methodology is based on: Matan, Anne and Peter Newman (2012), “Jan Gehl and new visions for walkable Australian cities”, World Transport Policy and Practice volume 17.

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 from 1 to 5 points.

➔ 0%: score 0
➔ 100%: score 10

g Calculation sheet
The calculation sheet contains 400 prepared input cells for the indicator. In each of these cells, the average score of an interview can be filled in. For each interview, two cells are provided: the first for the score (e.g. appreciation of a certain item) and the second to give a weight to the item (considered by the interviewee more or less important or relevant). The average weighted score per item is calculated automatically. If more surveys have been done, the input columns can be extended, but the calculation of the final score has to be adapted for the indicator.

h Notes
- Successful public spaces have four key qualities: they are accessible; people are engaged in activities there; the space is comfortable and has a good image; and finally, it is a sociable place – one where people meet each other and take other people when they come to visit (source PPS).

- 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.

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 birds’-eye distance of 400 meters from a public transport stop (including paratransit such as microbuses) or 800 meters from a rail transport stop. In addition to radial bird’s-eye 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 bird’s-eyes 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

$$AccI = \frac{\sum_i (PR_i)}{Cap} = 1 - \frac{\overline{PR}}{Cap}$$

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 meters for train, metro or car sharing station, 400 meters for bus or tram stop or bike sharing station not yet counted in another mode range [#]

$\overline{PR}$ = number of people living in an area not covered by the acceptable radius net

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. For cities that have an elaborated GIS of the street and public services networks, it is recommended to use real walking distances along the street network instead of the 400 meter and 800 meter radius. Walking distances of 500 and 1,000 meters can then replace the radius of 400 and 800 meters. Also, when working with the radius approach, physical barriers such as rivers, motorways, railways should be taken into account (eliminating the areas beyond these 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

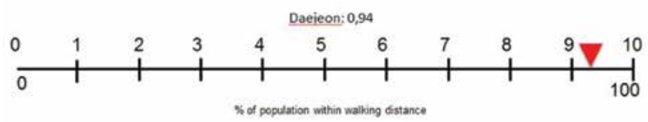
The proposed limit of 400 meters and 800 meters is based on the following literature sources:

- 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 640 metres. For rail, underground and light rail services the maximum walking time is defined as being 12 minutes 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 Calculation sheet

The calculation sheet contains prepared input cells for the input variables mentioned above(d. Formula & calculation method).
The indicator value is calculated automatically.

h 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.

- 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.

- Replacing this parameter by “Access to urban infrastructure” (recommendation of the Assurance Panel) was rejected because of difficult attainability (need for a lot of geographical and transport data, complicated GIS calculation).

Traffic Safety

a Definition

Road and rail transport accidents in the city and damage caused

b Parameter

Fatalities 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]

$\mathbf{K_i}$ = Number of persons killed in transport mode i [# per year]

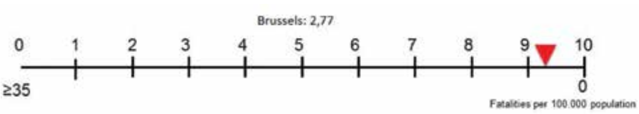
Cap = Capita or number of inhabitants in the city [#]

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

e Source

Proposed methodology is based on:
Global Cities Institute (2013), Global City Indicators, "Profile Indicators" , p. 2; http://www.cityindicators.org/Default.aspx. National/regional or city data sources or World Bank/UN Global Indicators databases.
(Referring to road casualties, in the proposed WBCSD SMP2.0 methodology rail casualties have to be added.)

f Scale



➔ 0: 35 fatalities
➔ 10: 0 fatalities/100.000 capita, "Vision zero" objective
➔ Egypt, 2000: 42 fatalities per 100.000 pop.
➔ Definition of fatalities: died within 30 days after the traffic accident as a corollary of the event

g Calculation sheet

The calculation sheet contains prepared input cells for the input variable Ki (= Number of persons killed in transport mode i) for the following modes: pedestrian, bikes, moped, motorcycles, cars, trucks, bus, train, tram, underground/metro, boat, helicopter, unknown (3 more types can be added).

Cap = Capita or number of inhabitants in the city is copied automatically from the general input sheet towards the indicator sheet.
The indicator value is calculated automatically.

h Notes

- Transport fatality means any person killed immediately or dying within 30 days as a result of a transport accident (all modes of transport).

- 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 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).

- The indicator is specified per population in order to avoid reflecting the city size and to validate all transport safety measures, independent from the technology used.

- The formulation of well-targeted policies and solutions, including accidents with injuries and even traffic accidents with only property damage, is in most cases to be recommended. These accidents are seen as sources for additional information to develop well-targeted measures. Police reports are a primary source for this information. Depending on the case, cities might even use data from hospitals, insurance companies or other major organizations in the city (schools, etc.), for example to formulate measures and solutions for bike accidents with school children. Standard weight factors, used to combine different severity of injuries and fatalities, are:
    - Weight factor 5 for a fatal accident
    - Weight factor 3 for an accident with seriously injured victim(s)
    - Weight factor 1 for an accident with slightly injured victim(s)

Definitions :

- Fatality: the usual international definition, as adopted by the Vienna Convention in 1968, is "A human casualty who dies within 30 days after the collision due to injuries received in the crash."

- The definition of a serious injury is less clear-cut and may vary more over time and in different places. The UK definition covers injury resulting in a person being detained in hospital as an in-patient in addition all injuries causing: fractures, concussion, internal injuries, crushing, burns (excluding friction burns), severe cuts, and severe general shock, which require medical treatment even if this does not result in a stay in hospital as an in-patient.

- The definition of a slight injury is even more unclear: it concerns injuries which are not judged to be severe.

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 L_{den} measurements.

c Methodology

➔ M5: Field measurement

The indicator is evaluated based on the percentage of the population hindered by city transport within certain noise levels based on random noise measurements

The number of people annoyed by traffic noise is based on field measurement of Lden at locations near a representative random selection of houses of city 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),

- Only the impact of traffic noise should be included.

- During the measurements, other sources of noise that might be disturbing the measurements are noted (e.g. person mowing the lawn, etc.). 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 MWFi (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:

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 roads
- o 10 locations near access road to the city center
- o 10 locations within typical living neighborhoods
- 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.)

	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, whichever 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 a 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 (distance 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 greenery, etc.
    - o Weather conditions (sun, cloudiness, wind, rain, etc.)

Figure 9: Examples of traffic noise measurement locations

Calculation OF L_{den}:

Lden is defined in terms of the "average" levels during daytime, evening, and night-time, and applies a 5 dB penalty to noise in the evening and a 10 dB penalty to noise in the night. The definition is as follows:

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

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

$$NI = \frac{\sum_i (MWF_i * HFLden_i)}{\sum_i (MWF_i)}$$

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

NI = Noise hindrance index [% of population]

i = Measurement number [#]

MFWi = 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 L_{den} values

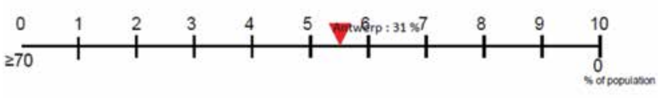
1	if Lden > 84 dB(A)
0.9	if Lden > 81 dB(A)
0.8	if Lden > 78 dB(A)
0.7	if Lden > 75 dB(A)
0.6	if Lden > 71 dB(A)
0.5	if Lden > 67 dB(A)
0.4	if Lden > 62 dB(A)
0.3	if Lden > 57 dB(A)
0.2	if Lden > 49 dB(A)
0.1	if Lden > 37 dB(A)
0	if Lden < 37 dB(A)

Source Miedema, H.M.E. and H. Vos (1998), "Exposure-response relationships for transportation noise," J. Acoust. Soc. Am. 104(6), 3432-3445.
For relevance, see: McGuire, S. and P. Davies (2008), *An overview of methods to quantify annoyance due to noise with application to tire-road noise.*

e Source

Proposed methodology is based on measurements campaign in the frame of the EU noise directive during the period 2005-2010.

f Scale



g Calculation sheet

The calculation sheet contains prepared input cells for the input variables Ldeni and MFWi (weight factor) for the locations mentioned in c. Methodology description. The number of hindered HFLdeni is calculated automatically as well as the indicator value.

Next to the indicated measuring points, e.g. for specific city situation, 10 more measuring points (types) can be added. If, because of the situation, less measuring points are selected than recommended, the corresponding cells can be left blank

h Notes

- Exposure to traffic noise resulting from road and freight transport.

- Traffic noise by city transport includes road and rail transport.

- The percentage of the population is introduced to avoid reflecting the city size and to validate noise abatement measures related to vehicles as well as to infrastructure, independent of the technology used.

- The measurements take place in front of houses at selected locations, applying a weight factor for its relevance (i.e. density of population).

- Research has resulted in defining the relation between a given noise level (Lden in dbA) and annoyance levels.

Air polluting emissions

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: Calculation (traffic model)
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. Alternative methods are field surveys (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 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-kilometers 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:

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

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, etc.) [type]

i = Vehicle type 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]

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

c = Emission class (euro norm) [type]

e Source

Preferably, specific national values are used for the conversion factors in order to make calculations specific for the city in case. 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; thanks to a central vehicle register, the differentiation between passenger cars, LDV, HDV and two wheels can be made. For the differentiation into vehicle technology classes for each of these, previously named extra information is required and is assumed to be available from the appropriate city services. For Belgium, the information about the vehicle fleet is available at

http://www.mobilit.belgium.be/nl/binaries/stats_soort_nl_tcm466-240222.pdf.

E_{ijkcs} factors are, for example, provided by the EMEP/EEA in [EMEP/EEA Emission Inventory Guidebook 2009, 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 Eeqs 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”:

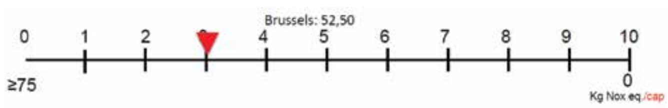
Pollutant	Relative importance (based on 2007USD) with NOx, cost as reference
NO_x	1.00
PM_{10}	1.06

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

In contrast to the climate change issue where relative impact of all greenhouse gases can be compared thanks to CO_2 equivalents, here monetary values are used as a starting point to calculate the mutual weight of the pollutants in their impact on air quality because of a lack of information concerning other non-monetary equivalence factors for all of the listed air pollutants. Eeq values differ between countries because of different monetary value calculations and currencies (and time aspects), as illustrated in the table above; each European Union member state has its own emission costs per tonne.

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).

f Scale



➔ 0: 10 kg NOx eq. per capita per year
➔ 75: 0 kg NOx eq. per capita per year

g Calculation sheet

- As for the sheets for energy efficiency and GHG, the calculation sheet for this indicator contains different energy intensity factors (kg, kWh or l per km) for different energy products – called "fuel types" in the sheet – used for urban transport (gasoline, diesel, CNG, LPG, heavy oil, ethanol, bio-ethanol, bio–diesel, hydrogen, electricity, coal). "Hybrid" is also mentioned in this column; cities have to identify if this category is relevant in the local context, and if so what combination of "fuel types" have to be used (result input in "Default Value" sheet).

- The energy products mentioned are also repeated in the calculation of the energy consumption for the different modes. The vehicle-kilometers driven in the city by these modes must be put in the calculation sheet in the relevant cells. This information can be based on traffic modelling or other sources mentioned. In the sheet there is also a column to put in the shares of the different fuel types (Sjk) for each mode; these shares have to be found in national databases if the city has no specific dataset on this breakdown.

b Notes

- The indicator is focused on the most relevant harmful emissions endangering public health: NOx and PM10. Though PM2.5 is also mentioned more and more in literature as an important threat to public health in cities, the emissions data are not commonly available. Other harmful pollutants (CO, HC, SOx) are also not considered in the parameter calculation, not only to limit the data collection to feasible limits for most of the cities, but also due to a lack of adequate theoretical values to aggregate the results (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 as emissions per city. 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 avoid reflecting the city size and to validate the effect of measures reducing the emission of the vehicle park and the smoothing of traffic flow.

Comfort and pleasure

a Definition

The physical and mental comfort of urban transport and services for all people

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. A proposal for a survey form is attached in annex D. 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.

- 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.

Questions covering quality of the city transport system based on topics:

- Pleasure of walking or riding different vehicles in the city
- Business, crowding (m^2 per passenger, number of seats/passenger, etc.)
- Space per passenger
- Cleanliness, maintenance

Punctuality, fares, sales channels, PT stops and infrastructure, number and frequency of PT

d Formula & calculation method

Average reported satisfaction about comfort of city transport by all people.

$$COMFsc_{av} = \sum_{i} \frac{(COMFsc_i)}{i}$$

$$COMFsc_i = \frac{\sum_{j=1}^{m} Q_j * W_j}{\sum_{j=1}^{m} W_j}$$

$COMFsc_{av}$ = Average city transport physical and mental comfort score [%]

$COMFsc_i$ = Weighted city transport physical and mental comfort for surveyed person i [%]

i = Number of persons in survey [#]

Q_j : Score on the quality questions [#]

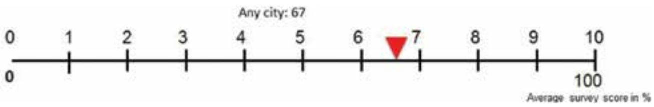
W_j : Score on the importance questions [#]

m = Number of topics handled [#]

c Source

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



➔ Reported average satisfaction on a scale of 5 points
➔ 0: 0
➔ 10: 100

g Calculation sheet

The calculation sheet contains 400 input cells for the indicator. In each of these cells the score of an interview can be filled in. For each interview question per interviewee, two cells are provided: one for the score (e.g. appreciation of a certain item) the other to give a weight for the item (considered by the interviewee more or less important or relevant). The average weighted score per item is calculated automatically. If more surveys have been done, the input columns can be extended, but the calculation of the final score has to be adapted for the indicator.

h Notes

- Comfort of urban public transport includes crowding, quality of equipment, toilets (e.g. on trains and train stations), services (e.g. availability of food on trains), age of equipment, cleanliness of mailing and (small) package delivery services, equipment, etc. 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.

- Non-users must be considered as well as users.

- Access to freight transport by citizens covers suitable package delivery services.

- The indicator also refers to types or aspects of urban travel considered as enjoyable by the people travelling.

- 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.

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. A proposal for a survey form is attached in annex D. The target population is selected groups: 65+, people with (registered) visual disabilities or reduced mobility, pregnant women.

Questions covering topics:
- Physical barriers
- Orientation and warning, relevant for blind and visually disabled
- Bus stops and shops
- Orderliness
- Benches and chairs
- Availability of transport service for disabled persons Availability of adapted cars for disabled persons (affordability, financial support, shared cars, etc.).

d Formula & calculation method
The variable is the average survey score.

$$AccDGsc_{av} = \frac{\sum_i (AccDGsc_i)}{i}$$

$$AccDGsc_i = \frac{\sum_{j=1}^{m} Q_j * W_j}{\sum_{j=1}^{m} W_j}$$

AccDGsc$_{av}$ = Average accessibility for deficiency groups score of city transport [%]

AccDGsc$_i$ = Weighted accessibility score of city transport for surveyed person i [%]

i = Number of persons in survey [#]
selected groups: 65+, people with (registered) visual disabilities or reduced mobility, pregnant women

Q$_j$: Score on the quality questions [#]

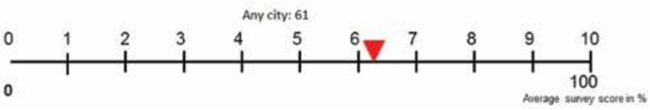
W$_j$: Score on the importance questions [#]

m = Number of topics handled [#]

e Source
Proposed methodology is based on:
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.

Durvey 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 Calculation sheet
The calculation sheet contains 400 input cells for the indicator. In each of these cells the score on each interview element can be filled in. For each question, two cells are provided: one to fill the score (e.g. appreciation of a certain item) and the other to give a weight for the item (considered by the interviewee more or less important or relevant). The average weighted score per item is calculated automatically. If more surveys have been done, the input columns can be extended, but the calculation of the final score has to be adapted for the indicator.

h 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 walkways and in railway stations, seats reserved for disabled people and the elderly in buses, reserved parking spaces for the disabled.

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 25th percentile of the population

b Parameter

Affordability index 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]

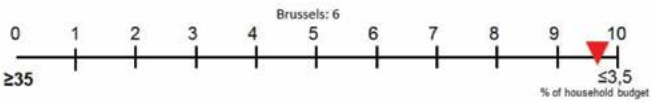
i = Available public transport mode [type]

60 = sixty trips per month

e Source

Based on methodology used by the World Bank in Latin American cities, see:
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 Calculation sheet

The calculation sheet contains prepared input cells for the input variables mentioned above(d. Formula & calculation method).
The indicator value is calculated automatically.

h 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 numbers of 60 necessary trips per month is assumed.

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
The outline of the "Survey" methodology is described in the general part. A proposal for a survey form is attached in annex E. 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.

- 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.

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 of crime in car traffic
- Risk of theft in freight transport

d Formula & calculation method
The parameter is the average survey score.

$$SECsc_{av} = \frac{\sum_i SECsc_i}{i}$$

$$SECsc_i = \frac{\sum_{j=1}^{m} Q_j * W_j}{\sum_{j=1}^{m} W_j}$$

$SECsc_{av}$ = Average crime-related security score [%]

$SECsc_i$ = Weighted crime-related security score for surveyed person i [%]

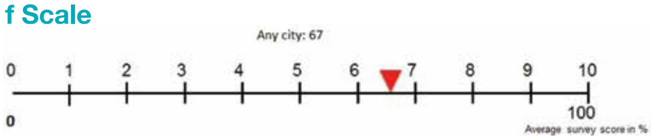
i = Number of persons in survey [#]

Q_j: Score on the quality questions [#]

W_j: Score on the importance questions [#]

m = Number of topics handled [#]

e Source
Proposed methodology is based on:
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


➔ Reported average satisfaction on a scale of 5 points
➔ 0: 0
➔ 10: 100

g Calculation sheet
The calculation sheet contains 400 prepared input cells for the indicator. In each of these cells an average score of an interview can be filled in. For each interview, two cells are provided: one to fill the score (e.g. appreciation of a certain item) and the other to give a weight for the item (considered by the interviewee more or less important or relevant). The average weighted score per item is calculated automatically. If more surveys have been done, the input columns can be extended, but the calculation of the final score has to be adapted for the indicator.

h Notes
- Incidents include: property offences, physical offences against passengers and offences against operatives.

- Apart from the real security, the perceived security is also an important issue in the frame of sustainable urban transport because security should give users confidence that they can use transport. The lack confidence can lead to non-compliance with mobility needs.

- Subjective security related to crime covers day and night situations in different transport mode environments such as (underground) parking, streets and squares, stations and bus stops, public transport rides, etc.

- Women transport users have to be sufficiently represented in the survey.

Functional diversity

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 1 km x1 km. The presence of 10 functions (listed above) is indicated in each of the grids and weighted with the population living in the area.

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

With:

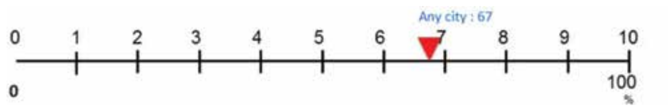
FDS= Functional diversity score[%]
Popi= Fraction of population in the city in zone i [fraction]
Presij= Presence of functions j in zone i (it is equal to 1 if there is a presence; it is equal to 0 if there is not a presence) [binary]

e Source

It concerns a newly developed survey for WBCSD SMP2.0. The methodology is in fact 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: Reported average satisfaction on a scale of 0 to 100%, based on individual scores on the different questions from 1 to 7 points.
➔ 0: average score 0%
➔ 10: average score 100%

g Calculation sheet

The calculation sheet contains 6x10 prepared input rows. In each of the cells of the first input column either "1" (present) or "0" (not present) has to be put in depending on the presence of the indicated function in the zone concerned. For each zone, the fraction of the population living in that zone has to be inserted. If more zones exist in the city, the input columns can be extended, the calculation of the final score has to be adapted for the indicator.

h Notes

- The indicator is complementary to the commuting travel time indicator. This indicator 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 easy 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. However, it is preferable to stick to 10 categories and to choose the function types in relation with daily mobility needs.

a Definition

Intermodal connectivity of city transport offered by the physical presence of intermodal interchanges in the transport network

b Parameter

Number of intermodal interchanges (i.e. number of park and rides (P+R), interchanges between different PT modes, PT stop or stations offering shared bikes availability - relative to the surface of the city)

c Methodology description

➔ M2: (Spatial data) analysis

All the interconnection points are identified based on information from public transport companies, parking companies, providers of shared bikes. If it exists, an overview map from the urban mobility plan can be used too.

Interconnection points include: interchanges between two different public transport modes (e.g. bus, tram, metro, train), P+R ride facilities, stations or stops providing shared bikes, organized bike parking, etc. If two or more modes are interconnected, the point is m-1 times counted (or weighted with that value), with m representing the number of interconnecting modes.

Only public transport services with a minimum frequency of one per two hours (off peak) and one per hour (peak) are considered. At least 10 parking spaces and 5 public bikes have to be provided to account for these types of intermodal connectivity.

If GIS maps exist, the (weighted) counting can be executed automatically; if not, a manual count per mode or per point has to be done.

d Formula & calculation method

$$INF = \frac{\left(\sum_i (IC_i)\right)}{Surf}$$

INF = Intermodal connectivity index [index]

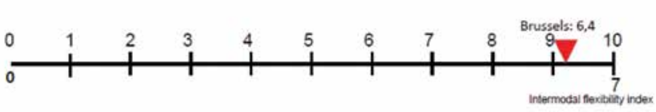
IC$_i$ = Intermodal connection point i, i.e. interchanges between different public transport modes (e.g. bus, tram, metro, train), P+R ride facilities, stations or stops providing shared bikes, organized bike parking, etc. [#]

Surf = Surface of the city in square km [km^2]

e Source

Newly developed parameter for WBCSD SMP2.0
LUYBEN, K. (2010), *Designing robust road networks*.

f Scale



➔ 0: ICi = 0
➔ 10: ICi = 7

g Calculation sheet

The calculation sheet contains a matrix. In the first column of this matrix, the names of stations and stops can be filled in. In the next columns, the corresponding modes can be indicated per row (i.e. station or stop). The number of interconnections and the weight factors are calculated automatically.

h Notes

- The indicator is complementary to the congestion and delays indicator, which counts for the time dimension of reliability. This indicator covers the spatial dimension of connectivity and reliability of the urban transport system: are there alternative transport modes to reach the destination within a reasonable time frame if the preferred way of travelling is disturbed or not available?

- The indicator is also complementary to the intermodal integration indicator. Physical features, such as parking size and signposting at the intermodal nodes and the integration of the organization of the systems, are not taken into account in the intermodal connectivity indicator. Reference to qualities such as parking capacities is made in the intermodal integration indicator survey.

- Bike sharing systems offered at P+R facilities and public transport stations are also considered. Car sharing is not as it is considered a more independent system that is not used in combination with, for example, regular public transport. Two-way car sharing especially cannot be used for intermodality, as floating car sharing cannot ensure the presence of cars at the node when people need them. Only station-based one-way car sharing could be considered.

Intermodal integration

a Definition

Quality of the interchange facilities between different transport modes

b Parameter

Reported quality of interchange facilities between different transport modes referring to integration of organization of the subsystems and the physical quality of the interchange facilities

c Methodology description

➔ M2: Survey

The outline of the “Survey methodology” is described in the general part. A proposal for a survey form is attached in annex E. The target population is users and non-users of intermodal connections.

- 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.

- 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 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).

As with the other surveys, interviewees are asked to give a weight of importance (value 2, 1 or 0) and a score from 1 (most unsatisfied) to 5 (most satisfied) for each question.

d Formula & calculation method

$$QIntsc_{av} = \frac{\sum_i (QIntsc)_i}{i}$$

$$QInt_{sci} = \frac{\sum_{j=1}^{m} Q_j * W_j}{\sum_{j=1}^{m} W_j}$$

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

$QIntsc_i$ = Average weighted score quality of interchanges for surveyed person i [%]

i = Number of persons in survey [#]

Q_j: Score on the quality questions [#]

W_j: Score on the importance questions [#]

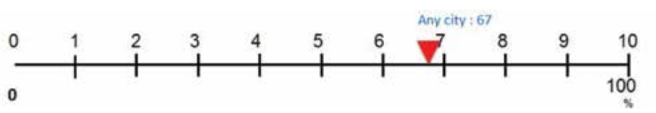
m = Number of topics handled [#]

e Source

IIt concerns a newly developed survey for WBCSD SMP2.0. However, there is a longstanding tradition of surveying user and non-user satisfaction with transport services.

On reliability of networks:
OECD (2010), *Improving Reliability On surface Transport Networks,* OECD: *Paris*.

f Scale



➔ Scaling: Reported average satisfaction on a scale of 0 to 100%, based on individual scores on the different questions from 1 to 5 points.

➔ 0%: score 0
➔ 100%: score10

g Calculation sheet

The calculation sheet contains 400 prepared input cells for the indicator. In each of these cells the score of an interview can be filled in. For each interview question two cells are provided: one to fill the score (e.g. appreciation of a certain item) and the other to give a weight for the item (considered by the interviewee more or less important or relevant). The average weighted score per interviewee is calculated automatically. The results for each interviewee are calculated into the indicator value. If more surveys have been done, the input columns can be extended, but the calculation of the final score has to be adapted for the indicator.

h Notes

- The indicator is complementary to the intermodal connectivity indicator that accounts for the presence of interchanges at network level.
- The indicator is also complementary with the comfort and pleasure indicator that accounts for the quality of the different transport modes separately.
- The quality of interchanges between different public transport modes (e.g. between train and bus) are included in this indicator.
- Bike sharing systems offered at public transport stops or stations and at P+R facilities are also considered.

Resilience to disaster and ecological/social disruptions

a Definition

Emergency response (time) and resilience of the transport system in case a major part of the network cannot be used or is damaged due to a disaster or disruption

b Parameter

The best possible evacuation time in hours, calculated as the total road capacity to cross the city border and screen lines (such as a river) per capita in the city to be evacuated plus the reaction and information time on possible evacuation directions.

c Methodology description

➔ M4: Analysis (spatial data) (GIS)

The most critical evacuation time in hours, calculated as the total road capacity to cross the city border and screen lines (such as a river) in the city per capita. This is calculated with existing data that should be available for every city.

The necessary data are:

- # inhabitants
- # of employed people not living in the city
- Number of lanes that cross the city border through which people can flee the city
- Introduction of communication technology (car radio, GPS or other communication tools) made available in the city
- Response time by travel information providers in case of disaster or disruption. These providers have good idea of how fast a situation is picked up and consequently distributed over the respective communication channels. This information can also be part of a city emergency plan.

d Formula & calculation method

In the formula, the premise is that the maximum amount of people that can be evacuated per hour for the city border and for all screen lines in the city center is:

$$CET = RIT + TT + \frac{Cap_{I\&C}}{n_{OL} * TPC}$$

$$RIT = \frac{RIT_{ped} * (CAP_{I\&C} - CAR_{reg})}{CAP_{I\&C}} + \frac{RIT_{car} * CAR_{reg}}{CAP_{I\&C}}$$

With:

$$RIT_{car} = TT_{car} + Average(RIT_{cartech\_i} / L_{cartech\_i})$$

$$RIT_{ped} = TT_{ped} + Average(RIT_{pedtech\_i} / L_{pedtech\_i})$$

and:

CET = Critical evacuation time on the most critical screen line [hours]

RIT = Reaction and information time on possible evacuation routes (by disaster and/or traffic management) [minutes]

$CAP_{I\&C}$ = Capita including commuters, i.e. number of people to be evacuated (inhabitants + persons normally working in the area) [#]

n_{OL} = Number of outgoing lanes through the critical screen line (if emergency plan foresees so, also some incoming lanes can be counted) [#]

TT = Travel time (average time to gathering point + average travel time from gathering point to screen line per car) [minutes]

TT_{car} = travel time (average time to car + average travel time from car collection point to getting in normal traffic) [minutes]

TT_{ped} = Travel time (average time to gathering point and expected waiting time for action from that point) [minutes]

TPC = Throughput capacity of the lanes (reasonable value is 7,200 persons per hour) being 1,800 vehicles per hour with 4 persons per vehicle) [persons/hour]

RIT_{ped} = Reaction and information time for pedestrians [minutes]

RIT_{car} = Reaction and information time for cars [minutes]

$RIT_{cartech\_i}$ = Reaction and information time via car-relevant information technology i [minutes]

Examples of $RIT_{cartech\_i}$:

RIT_{DRIP} = Reaction and information time via DRIPs [minutes]

RIT_{GPS} = Reaction and information time via GPS [minutes]

$RIT_{carradio}$ = Reaction and information time via car radio [minutes]

$RIT_{pedtech\_i}$ = Reaction and information time via relevant information technology i for pedestrians [minutes]

Examples of RITpedtech_i:

RIT_{mobile} = Reaction and information time via mobile phones [minutes]

RIT_{radio} = Reaction and information time via radio [minutes]

RIT_{smart} = Reaction and information time via smart phones [minutes]

$L_{cartech\_i}$ = Percentage of cars equipped with communication technology i [%]

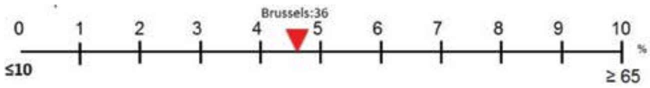
$L_{pedtech\_i}$ = Percentage of people who have communication technology i at disposal [%]

CAR_{reg} = Number of cars registered in the city [#]

e Source

Parameter developed for WBCSD-SMP2.0

f Scale



➔ 0: > 18 h
➔ 10: < 1 h

g Calculation sheet

The calculation sheet contains prepared input cells for the different input variables mentioned above under formula and calculation method. The indicator is calculated automatically.

h Notes

- The indicator could also be interpreted as the recovery speed of the city from a disaster. Because of the more direct link to mobility, the methodology of the evacuation speed of the city (or a part of the city) is preferred (time required to evacuate the area). This evacuation can be required as the city is subject to a (or an upcoming) disaster (tsunami, earthquake, nuclear incident, major industrial incident, etc.).

- The screen line in the city has to be defined based on the most critical virtual or real barrier in the city (e.g. a river).

- The time needed to inform the drivers of the possible (not blocked) evacuation routes (by traffic management systems and authorities and/or disaster planning coordinators) also has to be considered.

- Providing alternative routes and informing people is one way to respond. Technologies to communicate this, the respective reaction time as well as the implementation ratio of the technologies are part of the input data.

Occupancy rate

a Definition

Average load factor of vehicles of all modes of city transport

b Parameter

Weighted sum of average load factors per transport mode per vehicle distance on an average working day

c Methodology description

➔ M3: Calculation (traffic model)

The number of vehicle-kilometers per mode (car, motorbike, public transport modes, freight) is preferably collected by means of a traffic model. Alternative methods are field surveys (traffic counts on representative locations) or surveys (enquiring people's trip behavior). Of course, if these vehicle-kilometers are available in raw data banks, the available data can be used. This might especially be the case for public transport, which is reported in annual reports of public transport companies.

Load factors have to be derived from existing databases or (if not existing) from surveys. They are expressed in %. Values have to be considered for an average working day.

d Formula & calculation method

$$LF_{av} = \frac{\sum_i (LF_i * DF_i) + \sum_i (LP_j * DP_j) + (LC * DC) + (MC * DM)}{D_{tot}}$$

LF_{av} = Average load factor of city transport [fraction]

LF_i = Average load factor freight for freight mode i (as percentage of total moved capacity) [fraction]

DF_i = Total distance driven by freight mode i [million vehicle-kilometer per year]

LP_j = Average load factor (occupancy rate) of public transport mode j (as percentage of total moved capacity) [fraction]

DP_j = Total distance driven by public transport mode j [million vehicle-kilometer per year]

LC = Average load factor (occupancy rate) of transport by car (as percentage of total moved capacity) [fraction]

DC = Total distance driven by cars [million vehicle-kilometer per year]

MC = Average load factor (occupancy rate) of transport by motor cycle [fraction]

DM = Total distance driven by motor cycle [million vehicle-kilometer per year]

D_{tot} = Total Distance driven by the considered transport modes [million vehicle-kilometer per year]

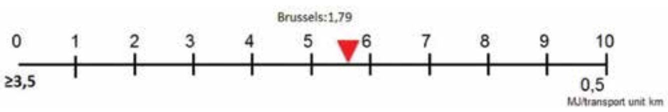
i = Freight mode number

j = Public transport mode number

e Source

Parameter developed for WBCSD SMP2.0
European Environment Agency (EEA) (2010), *Load factors for freight transport* (TERM 030), EEA: Copenhagen.
T. Joel, E. Taniguchi and A. Qureshi (2013), “Evaluation of Load Factor Control and Urban Freight Road Pricing Joint Schemes with Multi-agent Systems Learning Models”, Eighth International Conference on City Logistics, Bali

f Scale



➔ 0: ≤10
➔ 10: >65

g Calculation sheet

TThe calculation sheet contains prepared input cells for the different input variables mentioned above under formula and calculation method. For public transport as well as for freight transport, five vehicle categories are foreseen in the table.

D_{tot} is calculated as the sum of all considered modes. The indicator is calculated automatically.

h Notes

- The indicator expresses the efficiency of the use of the deployed means of transport.
- The utilization rate has direct consequences for the energy use per transported unit, thus having an impact on economic performance of transport and on the global environment. However, a 100% load factor is not attainable and also not desirable (when a passenger train is loaded 100%, it is not possible for extra passengers to get on board). An average maximum load factor of 65% is assumed to be a practical optimum. However, the maximum load of public transport (and other transport modes) is culturally influenced, so cities can adopt their own standards too.
- Occupancy rate is a particular indicator because the way to change it depends on the city strategy: either the city would like to provide a service and the public transport vehicles will run under-occupied during off-peaks, or the city would like to be cost-efficient and reduce frequencies but this directly impacts the quality of the service.
- Load factors can be derived from existing databases (or have to be calculated based on primary data) per type and mode of transport: freight, car and public transport.
- Motorcycles are included, mopeds and bikes excluded (because of the fuzzy definition of load factor for these modes).

Opportunity for active mobility

a Definition

Options and infrastructure for active mobility, which refers to the use of the modes walking and biking

b Parameter

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)

c Methodology description

➔M4: Analysis (spatial data) (GIS)

The indicator measures the spaces where active mobility is possible; therefore, indicator #12 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).

This ratio is preferably compared using spatial data and GIS. An alternative is using existing data.

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 [km]

L_{bl} = Length of road network with bike lanes [km]

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

L_{pz} = Length pedestrian zone [km]

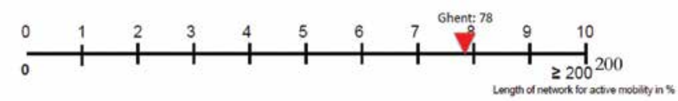
L_{rn} = Total length of city road network (excluding motorways) [km]

e Source

Parameter developed for WBCSD SMP2.0

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

f Scale



➔ 0: 0% road length

➔ 10: > 200%

g Calculation sheet

The calculation sheet contains prepared input cells for the input variables mentioned above (d. Formula & calculation method). The indicator value is calculated automatically.

h Notes

- Research shows an inverse relationship between average body mass index (BMI) of the population in a certain region and its modal split figures for walking and biking.
- More and more "hybrid" vehicles (combing 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. Walking and/or biking represent by far the most used active modes in all parts of the world.
- Only up standard facilities should be included. However, standards differ in different regions/ countries. A minimum width of 0.60 meters for sidewalks and 0.75 meters for bike lanes is generally accepted in technical guidelines.

Energy efficiency

a Definition

Final energy consumed for city transport

b Parameter

Final 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 surveys (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.

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).

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

E = Energy consumption rate [MJ / km]

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

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

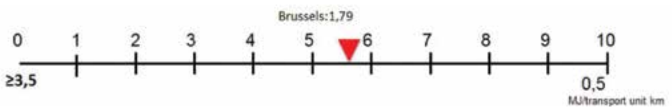
j = Vehicle class (if available specified by model e.g. SUV, etc.) [type]

e Source

The use of specific national values is preferable for the conversion factors in order to make calculations specific to the city in case. 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



➔ O: > 3.5 Mjoule/transport unit km

➔ 10: 0.5 Mjoule/transport unit km

g Calculation sheet

As for the sheets for *GHG* and *air pollution* the As for the sheets for GHG and air pollution, the calculation sheet for this indicator contains different energy intensity factors (kg, kWh or l per km) for different energy products – called "fuel types" in the sheet – used for urban transport. (gasoline, diesel, CNG, LPG, heavy oil, ethanol, bio-ethanol, bio–diesel, hydrogen, electricity, coal). "Hybrid" is also mentioned in this column; cities have to identify if this category is relevant in the local context, and if so what combination of "fuel types" have to be used. The energy products mentioned are also repeated in the calculation of the energy consumption for the different modes. The vehicle-kilometers driven in the city by these modes have to be put in the calculation sheet in the relevant cells. This information can be based on traffic modelling or other sources mentioned. In the sheet there is also a column to put in the shares of the different fuel types (Sjk) for each transport mode; these shares have to be found in national databases if the city has no specific dataset on this breakdown.

h 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). Only pump-to-wheel emissions are calculated. Thus things 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): 12.7 tonnes/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/occupancy-rates-of-passenger-vehicles-1#eea-comments).

- The definition focuses on energy resources for moving vehicles. 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.

- 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.

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The World Business Council for Sustainable Development (WBCSD), a CEO-led organization of some 200 forward-thinking global companies, is committed to galvanizing the global business community to create a sustainable future for business, society and the environment. Together with its members, the council applies its respected thought leadership and effective advocacy to generate constructive solutions and take shared action. Leveraging its strong relationships with stakeholders as the leading advocate for business, the council helps drive debate and policy change in favor of sustainable development solutions.

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