# DEVELOPING THE SUSTAINABLE URBAN TRANSPORT INDEX

Henrik Gudmundsson[1] and Madan B. Regmi[2]

## ABSTRACT

*The article describes the development of the Sustainable Urban Transport Index (SUTI) for cities in the Asia-Pacific region. The first step was designing a conceptual framework based on literature on sustainable development and transport while incorporating the Sustainable Development Goals (SDGs) of relevance for urban transport planning. The second step was to identify and select indicators for the index using literature, indicator criteria, and input from an expert group meeting. This led to a consolidated list of ten indicators. The final step was to construct the index itself. This involved decisions on ways to normalize, weigh and calculate the elements of the index. The resulting Second regional expert meeting expert endorsed the refined index with ten indicators and agreed for pilot application of SUTI in selected Asian cities. It is also recognized that additional work on data collection and analysis will be required to apply SUTI and regularly report and compare the performance of urban transport systems in cities in practice. The application of SUTI in four pilot cities is ongoing with preliminary results used for illustration. It is hoped that SUTI would be a useful tool to evaluate and assess the state of urban transportation systems in Asian cities. The analysis of urban transport systems would provide useful insights into policy suggestions and actions required for improving urban transport system and services. The SUTI would help measure progress in improving urban transport and contribute to the achievement of SDG target 11.2 on improving public transport in urban areas.*

**Keywords:** Urban transport, Assessment, Asian cities, Sustainable urban transport index, Policies

## INTRODUCTION

Sustainable transport is a major concern in connection with urban development worldwide, not least in the Asia-Pacific region (UN ESCAP 2016). The adoption of the United Nations 2030 Development Agenda with the 17 Sustainable Development Goals (SDG's) in 2015 has provided a new impetus to address the sustainability of transport systems and urban areas across the world. The New Urban Agenda that was adopted at the Habitat III summit in 2016 also emphasized the urgent need to tackle transport as part of wider urban development challenges (United Nations 2016). In October 2016, the United Nations Secretary Generals' High-Level Advisory Group on Sustainable Transportation submitted its report 'Mobilizing Sustainable Transport for Development ', calling for sustainable urban mobility plans that support intermodal and interconnected transport, and comprehensive monitoring and evaluation methodologies for sustainable transport by national and local governments (UN-HLAG 2016).

Today there is no comprehensive system in place to measure and report on sustainable transport across cities in the Asia-Pacific region. The UN ESCAP, therefore, initiated the Sustainable Urban Transport Index (hereafter: SUTI) project. The aim was to develop and demonstrate an index to measure sustainable urban transport and progress towards Sustainable Development Goals (SDGs) in Asian cities. The index is to serve as a tool to help summarize, compare and track the performance of cities across the Asia-Pacific region with regard to sustainable urban transport and the SDGs. The index has been developed with a view to balance between measuring what is necessary to support sustainable transport planning with the kind and scope of data likely to be operationally available for many different cities in Asia on a regular basis.

[1] CONCITO, Kattesundet 4, 3 fl., 1458, Copenhagen K, Denmark, hgu@concito.dk
[2] UN ESCAP, Transport Division, Bangkok, Thailand, regmi.unescap@un.org

Key aims in developing the SUTI has therefore been to,

- Reflecting SDG's and other sustainability concerns of relevance for urban transport
- Limiting the number of indicators to few most essential ones,
- Avoiding indicators that are overly demanding or sophisticated to collect, and
- Adopting an index calculation method that is as simple, transparent, and unbiased as possible.

The paper describes how these aims have been fulfilled.

## CONCEPTUAL FRAMEWORK

A conceptual framework is needed in order to design the scope of the index and the selection of indicators for the index. The key definitions and terminology for the conceptual framework are presented in table 1.

**Table 1. Key terminology for the framework**

**Indicator:** a variable selected to represent a key property of a system or a wider phenomenon of interest. Indicators may be used directly or as elements in other measurement tools.

**Index:** a special type of indicator that consists of two or more indicators that each measure distinct system characteristics in separate units that are normalized and aggregated.

**Framework**: A mental construct that serves to delimit and organize topics and associated sets of indicators or indices according to conceptual, operational and utilization concerns.

**Metrics:** The specific operational design of an indicator in regard to how the values are measured, parameterized, calculated, normalized, combined, etc. (e.g. as tons per capita, or per unit of GDP).

**Topic:** Phenomenon or system property that an indicator seeks to measure (for example 'transport demand', 'air pollution' or 'accessibility').

**Sustainable Development:** Meeting the needs of the present without compromising the ability of future generations to meet their own needs; measured according to the three dimensions of sustainable development, social, environmental, and economic.

**Sustainable Development Goals (SDGs) and Targets:** The 17 goals and 169 Targets for the period 2015-2030 adopted by the United Nations on September 25, 2015.

**Transport systems**: Infrastructure, vehicles, and propulsive energy jointly operated to deliver movement of people and goods.

**Domain**: An area of interest for monitoring and assessment consisting of several related topics. A group of indicators of such topics belong to a domain. In sustainable development assessment, the three dimensions are often considered as domains. In addition, the transport system is considered as a domain of indicators in sustainable transport assessment,

**Aspect**: Term used in this paper to describe three components of the conceptual framework: a) the main *services and impacts* that urban transport has in regard to the three dimensions of sustainability; b) the *SDG targets addressing urban transport*; and c) the generic *strategies* applied to pursue sustainability for urban transport, referred to as 'Avoid'. 'Shift' and 'Improve' strategies.

**City or urban area**: Built-up area with a high population density governed by one or more political/ administrative bodies. Not defined more specifically for this work.

The aim for the SUTI is to help measure and support urban transport for sustainable development. Fundamental concepts to incorporate in the framework, therefore, include sustainable development, transport, and how they connect in the urban context.

***Sustainable development*** is defined as in Table 1 according to the Brundtland report (WCED 1987). It represents a desired overall trajectory of development for people, the economy, and the planet as a whole. Sustainable Development has been made operational for the 2015-2030 period via the 17 SDG's and the associated targets.

***Transport systems*** form an integral part of society, the economy, and the human impact on the environment and they are therefore essential for sustainable development. The fundamental components of transport systems are infrastructure, vehicles, and propulsive energy operated by humans or computers. They deliver transport services, which include the movement of people and goods for a broad range of functions (Gudmundsson et al. 2016).

***Urban transport*** is a particular transport market that is separate from but interlinked with long-distance transport. Urban transport markets mainly serve needs to access work, education, retail options, health services, and social interactions. Urban transport service is provided by private, public and semi-public forms of motorized and non-motorized transport. In this context 'urban transport' is not defined more precisely than 'transport within in urban areas', since what is considered 'urban' differ across cities and countries.

***Sustainable transport*** is a term reflecting the need to govern transport according to sustainability. It has been defined in various ways but there is no agreement on a global definition (see e.g. Gudmundsson et al 2016, Ieda 2010, and Rand Europe 2004). The sustainability of transport systems is conditioned by the range of services and impacts produced by transport. These are ones such as accessibility, pollution, and safety. It can be pursued via a broad set of strategies (Banister 2008). Generic strategies include to *avoid* unnecessary transport, to *shift* transport from individual motorized transport to active modes and public transport, and to *improve* transport with regard to the use of efficient, clean vehicles and fuels.

Partly due to the complex and conditioned character of 'sustainable transport', there is not one dedicated SDG for transport in the 2030 Development Agenda. However, transport is important for achieving many of the SDG's, and several of the 169 specific SDG targets do address transport more directly.

Table 2 below highlights the SDG goals and targets that are most directly related to transport. Of these, some address urban transport directly (3.6. 9.1 and 11.2), while others refer to impacts such as energy and emissions where urban transport play important roles (especially 7.3, 11.6 and 13.2).

**Table 2. SDGs and targets of direct relevance for transport**

| Goal | Targets |
|---|---|
| 3. Ensure healthy lives and promote well-being for all at all ages | 3.6 By 2020, halve the number of global deaths and injuries from **road traffic accidents** |
| 7. Ensure access to affordable, reliable, sustainable and modern energy for all | 7.3 By 2030, double the global rate of improvement in energy efficiency (*) |
| 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation | 9.1 Develop quality, reliable, sustainable and resilient **infrastructure**, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all |

| | |
|---|---|
| 11. Make cities and human settlements inclusive, safe, resilient and sustainable | 11.2 By 2030, provide access to safe, affordable, accessible and sustainable **transport systems** for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons |
| | 11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management (*) |
| 12. Ensure sustainable consumption and production patterns | 12.c. Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances (*) |
| 13. Take urgent action to combat climate change and its impacts | 13.2 Integrate climate change measures into national policies, strategies and planning (*) |

(*) these targets do not explicitly mention transport systems, but transport actions are implied or will be instrumental for achieving them

Indicators are needed to make these targets operational, and actions are needed to achieve them. In summary, the conceptual framework for SUTI is understood in regard to three aspects,

- The main *services and impacts* that urban transport provides in regard to the three dimensions of sustainability.
- The *SDG targets* addressing urban transport.
- The generic *strategies* applied to pursue sustainability for urban transport.

The full conceptual framework is shown in Table 3. Each aspect is to be reflected in the construction of SUTI.

To further validate the framework, it was mapped on the 21 criteria in the 'meta-framework' for sustainable transport assessment developed by Cornet and Gudmundsson (2016). The mapping demonstrates that nearly all criteria are reflected in the framework (ESCAP 2017).

**Table 3. Summary of framework aspect and elements**

| Aspects | Elements |
|---|---|
| **Sustainable Development** | Economic Dimension impacts |
| | Social Dimension impacts |
| | Environment Dimension impacts |
| **Sustainable Mobility Paradigm** | Avoid strategy |
| | Shift strategy |
| | Improve strategy |
| **SDG Targets Relevant for Urban Transport** | 3.6 Deaths and injuries from road traffic |
| | 9.1 Quality, reliable, sustainable, resilient infrastructure |
| | 11.2 Access to safe, affordable, accessible and sustainable transport systems for all, |
| | 11.6 Adverse environmental impact including air quality |

| | |
|---|---|
| | 11.7 Universal access to safe, inclusive and accessible, green and public spaces |
| | *7.3 Improvement of energy efficiency (*)*<br>*13.2 Integrate climate change measures (*)* |

(*) represents a 'proxy target' as this element summarizes energy/climate aspects that are essential elements for sustainable transport impacts and strategies, but for which no direct transport SDG targets are formulated.

## INDICATOR SELECTION

Based on the conceptual framework the work to identify and select indicators involved three steps:

- Identification and organization of candidate indicators from the literature,
- Application of criteria to develop a consolidated indicator set
- Final adjustment of indicator set based on an expert workshop and a regional meeting.

This section explains these steps of the process.

### *Identification*

The identification of potential indicators starts from relevant literature, including scientific articles on sustainable transport measurement as well as more practice-oriented reports. This approach allows SUTI to be built primarily on existing work and recognized indicators, rather than requiring entirely new, non-established indicators. However, in a few cases, new indicators for important topics were developed as part of the process and final adjustment. The material was collected via previous research projects and supplementary literature search on key databases and internet sources.

The main focus of the literature review was publications reflecting a similar understanding of sustainable urban transport as in the conceptual framework. Attention was also given to identifying indicators actually applied to measure sustainable transport in several cities, and at best including cities in the Asia-Pacific region. In total around 25 indicators, publications were reviewed in detail. The full list is shown in the background report (ESCAP 2017). In addition to a range of scientific papers on sustainable transport measurement, the most valuable sources included four recent major efforts.

***The Sustainable Mobility 2.0 Project*** conducted by the World Business Council for Sustainable Development (WBCSD 2016). The project has developed a set of 19 urban transport indicators for use by cities worldwide. These had been applied in six cities, three of which are in Asia. A detailed methodology is offered that allows each city to operationalize the indicators.

***The Arthur D Little report "The Future of Urban Mobility"*** prepared for the International Union for Public Transport (UITP) (Arthur D Little 2014). The study also includes 19 urban transport indicators. 84 cities are covered, 30 of which in Asia-Pacific region. Case studies illustrate the range of data reported for each indicator for a selection of cities.

***The 'Sustainable Urban Transport Evaluation' (SUTE)*** system has been developed by the Korean Transport Institute and is applied annually to all major cities by the Korean government, using 24 indicators (KOTI 2015). 12 of the indicators are quantitative so-called 'status' indicators while 12 others represent more qualitative aspects of urban transport planning.

***The 'Inter-Agency Expert Group on Sustainable Development Goal Indicators'*** **(IAEG-SDG 2016)** has developed a global set of indicators that have been adopted by the United Nations Statistical Commission for tracking progress towards all of the SDG targets, including those mentioned in Table 2. The UN-HABITAT has made important contributions to addressing indicators to measure SDG goal 11 "Sustainable Cities and Communities", including a proposed indicator for target 11.2, which is the only

SDG target that deals explicitly with urban transport (Habitat 2016). These reports do not report any actual applications or data.

The indicator topics and specific indicator definitions in all of the 25 references were extracted to a spreadsheet database. The full database has in total 426 sustainable transport indicators. This set could be significantly condensed. First, many indicators across studies are identical or measure essentially the same variables. Others could be eliminated because they were either poorly defined, reflected less essential issues, or would likely require extensive effort to be applied in practice. The result of the condensation process was a shortlist of 20 'top' indicators reflecting key issues and with applications in practice. This list was organized into four domains, namely 'Transport system', 'Social impact', 'Economic impact', and 'Environment impact' indicators, following practice in literature on sustainable transport indicators (see e.g. De Gruyter et al. 2017; Gillis et al 2016; Martino et al 2010; Jean and Amekudzi 2005). The domains also reflect key aspects of the SUTI framework (Table 3). While the three latter domains refer directly to impacts of transport on each of the sustainable development dimensions, the 'transport system' domain is important in support of planning and management of transport.

***Indicator Criteria***

As 20 indicators were considered a too large set for realistic application to cities across Asia the shortlist was further narrowed to the final elements using a set of sustainable transport indicator selection criteria. As proposed by Castillo and Pitfield (2010) two sets of criteria were applied in this process:

a) Criteria aiming to maximize the relevance of indicators to the concept of sustainable transport. This was done by scoring indicators from 1-3 for each of the aspects of the SUTI framework

b) Criteria aiming to maximize the methodological quality of the indicators. The six criteria were,

- Definition and concept available in existing reports,
- Has been applied in practice in several cities,
- Data regularly available or readily produced,
- Clear interpretation possible,
- Scale to normalize indicator for the index can easily be defined,
- Relevant and actionable for cities.

Also, here a score of 1-3 was used. The scores for the two sets of criteria were summed for each indicator and a ranking of all shortlist indicators emerged (Table 4).

**Table 4. Combined ranking of sustainability and methodology.**

| Indicator | score |
|---|---|
| Air quality (pm10-pm2.5) | 177.78 |
| Access to public transport service | 176.92 |
| Walking and cycling networks | 170.09 |
| Share of active and public transport modes in modal split | 154.70 |
| Greenhouse gas emissions | 154.70 |
| Traffic fatalities [and serious injuries] | 147.86 |
| Transport fuel consumption | 97.44 |
| Costs of congestion | 94.87 |
| Access to urban functions (jobs, school, retail, health) | 93.16 |

| | |
|---|---|
| Access to transport system for vulnerable groups | 90.60 |
| Satisfaction with mobility services | 90.60 |
| Land occupied by transport infrastructure | 83.76 |
| Travel time to work | 79.49 |
| Noise levels | 79.49 |
| Public Transport reliability | 70.94 |
| Affordability of transport | 70.94 |
| Cars and two-wheelers per capita | 61.54 |
| Transport system costs to society | 18.80 |
| Security (crimes in transport) | 11.11 |
| Perceived economic opportunity | 11.11 |

***Final Adjustment***

This list was further reviewed by the project team, resulting in some modifications.

The shortlist indicator 'Walking and cycling networks' was redefined to measure existing urban transport plans in terms of how well they cover the alternative travel modes, including intermodal facilities. It was renamed as 'Extent to which transport plans cover public transport, intermodal facilities, and infrastructure for active modes'. This emphasizes the role of sustainable urban transport planning of cities.

The shortlist indicator 'Costs of congestion' was found too difficult to define and measure due to lack of agreed methodology, even if the concept itself is relevant. Instead of another economic indicator 'Affordability of transport' is included. Despite somewhat lower score in the indicator assessment, this is an indicator proposed in many studies, with direct relevance for the economic and social dimensions.

Another economic indicator that scored high, namely 'Transport fuel consumption' was omitted because of overlap with the environmental indicator 'Greenhouse gas emissions'. It was replaced by 'Transport system costs to society' with a definition related to the scale of investments, and renamed as 'Investment in public transportation systems'.

The project team proposed to limit the full set of indicators to the eight, two for each of the four domains. This number was considered reasonable in order to reflect the key domains as well as likely being manageable from an urban data collection point of view. Each domain would form a 'sub-index' of two indicators; the sub-indices would be aggregated to the full SUTI.

The SUTI conceptual framework approach and draft indicator set were presented for discussion at an Expert Group Meeting held in Kathmandu, Nepal, on 22-23 September 2016[3]. The experts were mainly urban transport expert representatives from Asian states and cities that are supposed to be the main users of the SUTI. It was considered more fruitful to invite the experts to confront an already elaborated concept with suggested indicators, rather than a so-called 'long list of indicators' that is prone to be less appealing.

One of the aims of the expert meeting was to discuss any needed adjustments to the preliminary selection of indicators proposed by the team. The experts discussed the proposed indicators with a view to their relevance, feasibility, and applicability to urban transport planning in Asian cities.

---

[3] http://www.unescap.org/events/expert-group-meeting-planning-and-assessment-urban-transportation-systems

The main critique was that the performance and operation of the transport systems were not sufficiently well represented in the indicator set. System performance is essential for agencies responsible for implementing urban transport strategies, who are to be users of the index. Also, additional economic factors were found to be important for sustainable management of urban transport systems, not least the operating costs. The outcome of this discussion was an endorsement of the proposed indicator set with adjustments as well as a request to include two additional indicators, which brought the total number of indicators to ten. In the 'transport system' domain was added: 'Quality and Reliability of public transport service'. In the 'Economy' domain was added: 'Operational costs of the public transport system'.

Moreover, it was proposed to dissolve the rigid allocation of each indicator to a single domain as some indicators relate to several domains. This is well in line with some sustainability theory, according to which the sustainability dimensions (corresponding to three out of four of the SUTI domains) are more to be seen as mental constructs than as separate physical systems (Joumard and Gudmundsson 2010, p 53). Therefore, the notion of building rigid 'sub-indices' within the overall SUTI was abandoned. Nevertheless, each of the three sustainability dimensions is still well represented in SUTI with at least two indicators of significance for each dimension.

The refined ten indicators set, normalization process and index design, as well as further description of indicators and data requirement and data standardization approach, was presented to the Region Meeting on Sustainable Transport Index held in Jakarta in March 2017[4] . The experts considered the refined SUTI and agreed for its pilot application in selected Asian cities and provided feedback on data collection and standardization. Table 5 shows the full set of indicators and illustrates which elements of the SUTI framework each indicator reflects.

**Table 5. Final set of indicators for the SUTI**

| Indicators | Dimensions | Strategies | SGD Targets |
|---|---|---|---|
| Extent to which transport plans cover public transport, intermodal facilities and infrastructure for active modes | System | Shift | (11.2) |
| Modal share of active and public transport in commuting | System | Shift | (11.2) |
| Convenient access to public transport service | Social. | Shift | 11.2 |
| Public transport quality and reliability | Social. | Shift | 11.2 |
| Traffic fatalities per 100,000 inhabitants | Social. | Improve | 3.6 |
| Affordability – travel costs as part of income | Economic. / Social. | Improve | (11.2) |
| Operational costs of the public transport system | Economic. | Shift/Improve | (9.1) |
| Investment in public transportation systems | Economic | Shift | (11.2, 9.1) |

[4] http://www.unescap.org/events/regional-meeting-sustainable-urban-transport-index

| | | | |
|---|---|---|---|
| Air quality (PM10) | Environmental. | Avoid/Shift/Improve | 11.6 |
| Greenhouse gas emissions from transport | Environmental. | Avoid/Shift/Improve | 7.3/13.2 |

***Indicator Descriptions***

In order to review the proposed indicators and to support the subsequent collection of data and standardization for each indicator, the following elements are considered and described.

*Indicator relevance for sustainable transport and the framework elements*: This element explains why each indicator is relevant for the conceptual framework.

***Proposed definition*****:** A specific definition of what is measured. In most cases, the definition is drawn from literature. In some cases, (such as indicator 1) it is defined especially for the context of the SUTI.
*Unit of measurement*. The metrics needed to actually measure and report the indicator (e.g. 'number of traffic fatalities per 100.000 inhabitants per year').

***Interpretation*****:** Two issues are considered here, a) to what extent the indicator has a clear interpretation with regard to sustainable transport. Only indicators with quite clear interpretation are included; b) the direction of change of the indicator that is positive and negative, respectively. For example, *declining emissions* are more sustainable. The direction for each indicator matters for calculating the index.

***Minimum and maximum values to use in the index construction*****:** To build a normalized index it is necessary to use a common scaling for all indicators (see section 4). 'Goalposts' in terms of what constitutes 'minimum' and 'maximum' performance values must be defined. Values for 'min' and 'max' were derived from the literature on transport situation for cities in Asia (if data were found) or around the world (if not).

***Sources in the literature*****:** This refers to key sources that have been used to identify and define the indicator.

***Data availability methods to provide data, and examples*****:** This section offers qualitative comments about expected data availability and examples on how to possibly collect or provide data for the indicator.

***Other comments:*** This addresses limitation of the proposed indicator and possible alternatives with regard to definition, measurement, delimitation, etc.

## INDEX DESIGN

In this section, the design of the index is presented. The section explains the choices made and alternatives considered with regard to three steps, namely normalization, weighting, and calculation.

### *Normalization*

Indicators on different scales need to be normalized before comparison and aggregation are possible.
The method applied uses linear rescaling which is a common approach in composite index design (Nardo et al. 2005) and often used for sustainable transport indices (Zito and Salvo 2010; Zheng 2013; Ahangani et al 2015). This allows for a simple transformation to a linear scale 1-100 for each indicator. Formula 1 is used,

$$Z_{i,c} = \frac{(x_{i,c})-(x_{min,i})}{(x_{max,i})-(x_{min,i})} * 100 \qquad \text{(Formula 1)}$$

Where,

- Z is the normalized indicator X for topic i and city c.
- $X_{min}$ is the lowest value of the indicator in actual units, whereas $X_{max}$ is the highest value.

The next question is how to define the goal posts, the min. and max. The min and max were defined as lowest and highest value found or expected for each indicator based on real performance information in the literature. Key sources to identify min and max values are mentioned under each indicator in the background report (ESCAP 2017). Another option would be to use a desired level to the max. In this study, this approach was used in a few cases, including for indicator 5 'Traffic fatalities' and indicator 10 'GHG emissions'. In both cases, the desired level is 0 (0 is therefore used as max value = best performance'). Political statements on Sustainable Transport like 'Bali Declaration' of 2013 explicitly speaks about zero-goals for accidents, pollution etc. (EST Forum 2013). A third option is to use relative ranking among the pool of observations that is, all cities (the min and max are set after worst and best city each year). This avoids the need to define the scale in advance. However, this method also makes it impossible to measure performance for one city in itself and to track progress over time for each city compared to other cities. Increase in rank among cities could be the result of other cities performing worse and thus misleading. For the Human Development Index (UNDP 2015) relative ranking was abandoned for this reason and replaced by fixed goal posts.

### *Weighting*

In constructing a composite index, it is necessary to decide how to weigh each element. Important elements affecting the desired outcome more than others should have a higher weight. Weights may be determined by statistical analysis or correlations (if data are available), by expert knowledge on the significance of each factor, or by political or subjective choice. 'Equal-weight' is obviously also a weighting choice.

In their sustainable transport indicator study, Zito and Salvo (2011) argue that by definition the three dimensions of sustainability should have equal weight in decision making. This is in accordance with a balanced view of sustainability. The same view is adopted by De Gruyter et al. (2017) in their recent study on sustainable transport for Asian cities.

However, as already mentioned, the framework adopted for SUTI does not recommend a rigorous balanced 'domain' approach, as several indicators overlap the domains. Instead, a formula is used that gives an equal weight of 0.10 to all of the ten indicators regardless of domain. This is considered the most reasonable approach, reflecting that all indicators can be considered important according to the selection process and the expert consultation, and no basis exists for assigning differentiated weights[5]. The indicators with weights and min and max values (section 5.1) are shown in Table 6.

---

[5] A weighting option is retained in the calculation sheet for the SUTI. This allows to test its sensitivity to different potential weighting schemes, and may become relevant in case it should be decided to introduce a weighing option for cities. When data has been collected for multiple cities, statistical analysis may be applied to derive differentiated weights.

**Table 6. Overview of SUTI with weights and min-max values.**

| No. | Indicators | Natural units | Weights | Normalization | |
|---|---|---|---|---|---|
| | | | | MIN | MAX |
| 1 | Extent to which transport plans cover public transport, intermodal facilities and infrastructure for active modest | 0 - 16 scale | 0.10 | 0 | 16 |
| 2 | Modal share of active and public transport in commuting | Per cent of trips/mode share | 0.10 | 10 | 90 |
| 3 | Convenient access to public transport service | Per cent of the population | 0.10 | 20 | 100 |
| 4 | Public transport quality and reliability | Per cent of satisfied with service | 0.10 | 30 | 95 |
| 5 | Traffic fatalities per 100,000 inhabitants | No of fatalities | 0.10 | 35 | 0 |
| 6 | Affordability – travel costs as part of income | Per cent of income | 0.10 | 35 | 3.5 |
| 7 | Operational costs of the public transport system | Cost recovery ratio | 0.10 | 22 | 175 |
| 8 | Investment in public transportation systems | Per cent of total investment | 0.10 | 0 | 50 |
| 9 | Air quality (PM10) | µg/m3 | 0.10 | 150 | 10 |
| 10 | Greenhouse gas emissions from transport | Tons | 0.10 | 2.75 | 0 |
| | | | 1.0 | | |

***Calculation Method***

There are different possible formulas to use to aggregate results from the indicators. Two basic options are to use either arithmetic mean or geometric mean.

The arithmetic mean is additive. The components are added together and divided by the number of components. However, there has been some critique of the additive index. First of all, this assumes linear substitution between the elements. One unit of negative change e.g. traffic accidents can be compensated by one-unit positive change in accessibility. This is not necessarily acceptable. It is also observed that ranking in the additive index is sensitive to a possible change of goal posts. These critiques informed the UNDP to change the calculation of Human Development Index to the geometric mean method (UNDP 2015).

For SUTI both methods were tested using partly hypothetic yet realistic data. The test showed that the SUTI results (ranking of cities) in some cases could be affected by the choice of aggregation method. Based on the similar argument as for the HDI it was decided to apply the geometric mean for aggregation, using Formula 2.

$$SUTI = \sqrt[10]{i1 * i2 * i3 \ldots * i10} \qquad \text{(Formula 2)}$$

A formula for a weighted geometric mean is also developed but not applied.

## EXEMPLIFICATION OF PRACTICAL CALCULATION

The procedure to calculate results has two levels. Both levels can use the Data Sheet developed as part of the project to calculate and analyse SUTI.

The first level is individual cities collecting data for the ten indicators and entering them in the SUTI Data Sheet for an individual city. There are ten cells to fill in, one for each indicator. When data are entered, normalized values are automatically calculated in a lower table, and a spider diagram is derived. The diagram shows the city's performance within the min-max scale for all ten indicators without aggregation to one index (table 7). The performance on each indicator scale indicates where the city is compared to min and max values for cities as described in section 4.2. To support the calculation of each indicator the full Data Sheet is also included sub-sheets for each indicator. These offer procedures, tables and formula for deriving the respective SUTI indicator from collected data. The mainsheet for calculating SUTI is available at the website (ESCAP 2017).

The second level is that cities collect data and submit them to a coordinating agency such an ESCAP who enters data into the SUTI sheet for multiple cities. For each city, there are the same ten cells to fill in, one for each indicator. When data are entered, normalized values are automatically calculated in a table and a spider diagram derived. The spider diagram shows all the cities' performance within the min-max scale for all ten indicators, allowing comparison across cities for each indicator. The sheet also calculates an aggregate SUTI value for each city. This allows for ranking the performance of cities according to the SUTI value if so desired. If actual data are collected for a significant number of cities (say, from 20 to several hundred) it is not practical to include all results in one spider diagram. An option to enhance diagram based comparisons of multiple cities in addition to comparing the aggregate SUTI ranks would be to break down the population into smaller, comparable groups of cities e.g. cities of similar size, cities in a sub region, or cities with similar geographical features.

Two examples were developed to illustrate SUTI. The first example shows the use of the index for a single city to assess its performance. The second example shows SUTI, for comparing and potentially ranking across four cities. Both examples are based on data from actual cities. However, the data and results are preliminary and not finally verified. Therefore these results should not be used for real comparing or ranking of the example cities.. Table 7 shows the actual and normalized values for one individual city called 'City X' as entered and calculated in the sheet.

**Table 7. Actual and normalized valued for City X**

| No. | Indicators | Natural Units | Weight | Range | | Actual Values | Normalized Values |
|---|---|---|---|---|---|---|---|
| | | | | MIN | MAX | | |
| 1 | Extent to which transport plans cover public transport, intermodal facilities and infrastructure for active modes | 0 - 16 scale | 0.1 | 0 | 16 | 12.00 | 75.00 |
| 2 | Modal share of active and public transport in commuting | Trips | 0.1 | 10 | 90 | 27.00 | 21.25 |
| 3 | Convenient access to public transport service | Per cent of population | 0.1 | 20 | 100 | 50.00 | 37.50 |
| 4 | Public transport quality and reliability | Per cent of satisfied | 0.1 | 30 | 95 | 52.50 | 34.62 |
| 5 | Traffic fatalities per 100,000 inhabitants | No of fatalities | 0.1 | 35 | 0 | 2.10 | 94.00 |
| 6 | Affordability – travel costs as part of income | Per cent of income | 0.1 | 35 | 3.5 | 18.20 | 53.33 |
| 7 | Operational costs of the public transport system | Cost recovery ratio | 0.1 | 22 | 175 | 55.40 | 21.83 |
| 8 | Investment in public transportation systems | Per cent of total investment | 0.1 | 0 | 50 | 50.00 | 100.00 |
| 9 | Air quality (pm10) | μg/m3 | 0.1 | 150 | 10 | 75.00 | 53.57 |
| 10 | Greenhouse gas emissions from transport | Tons | 0.1 | 2.75 | 0 | 0.53 | 80.73 |

**Figure 1. Example of City X performance for the SUTI indicators**

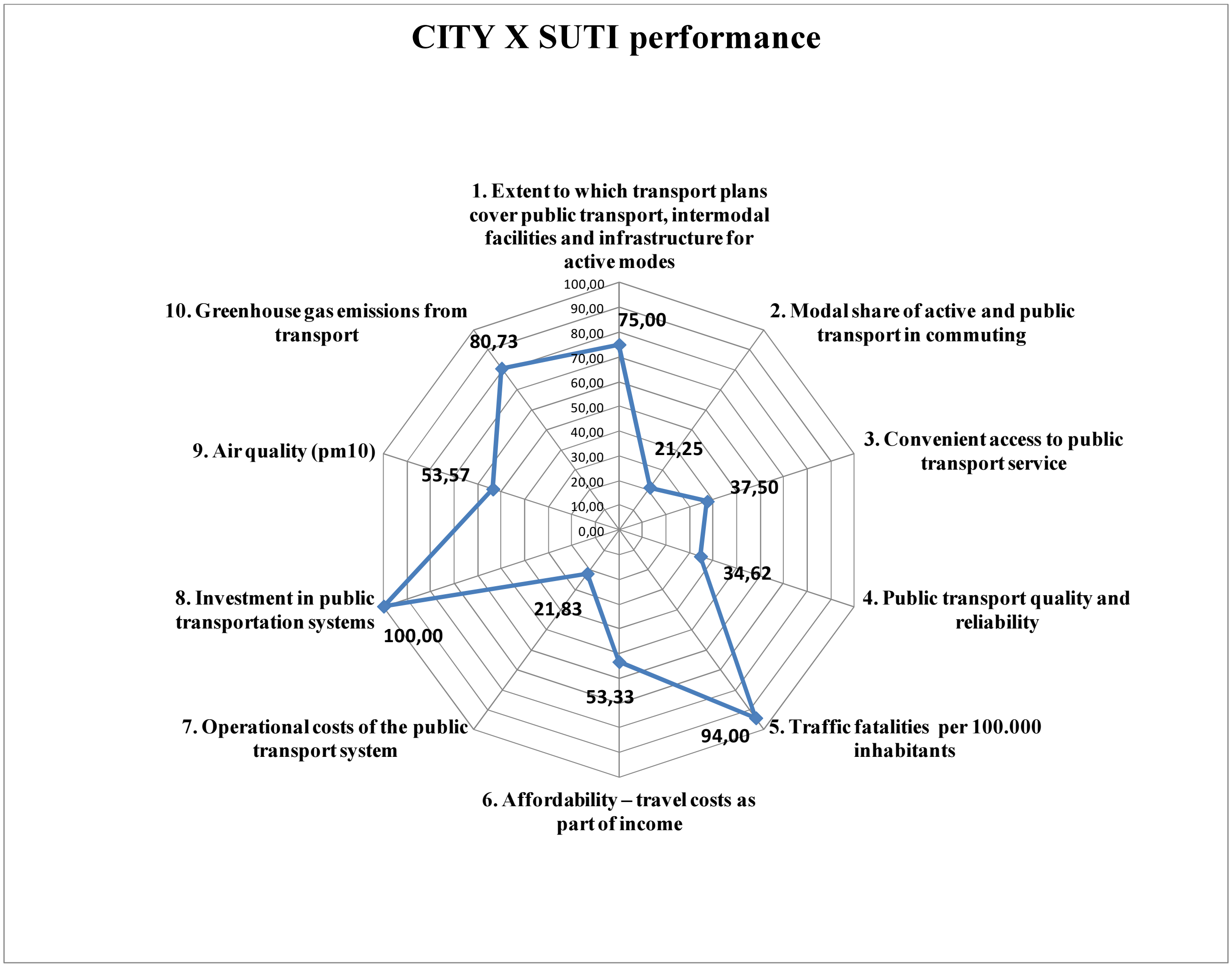



Figure 1 shows the resulting spider diagram for City X. Each 'corner' represents one of the ten indicators and the rings show levels of performance from min (at centre) to max (outer rim). The city can immediately observe areas where it performs well compared with the expected range of low to high performance. For example, for indicator 5 (fatalities), and 8 (investments) the city performs particularly well, whereas indicator 3 (modal share), and 7 (operational costs) performance is much less impressive. The information allows the city to begin contemplating strong and weak points as well as potential policy measures to enhance sustainability.

Table 8 illustrates preliminary data for a set of four cities for each indicator. Normalized values are calculated automatically in the same way as for the individual city indicator and a diagram is derived.

**Table 8. Data entries (actual and normalized) for four cities[6]**

| S. No. | Indicators | Actual values | | | | Normalized values | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Greater Jakarta | Hanoi | Kathmandu | Colombo | Greater Jakarta | Hanoi | Kathmandu | Colombo |
| 1 | Extent to which transport plans cover public transport, intermodal facilities and infrastructure for active modes | 12.00 | 7.00 | 7.00 | 11 | 75.00 | 43.75 | 43.75 | 68.75 |
| 2 | Modal share of active and public transport in commuting | 27.00 | 10.65 | 69.77 | 75.45 | 21.25 | 0.81 | 74.71 | 81.81 |
| 3 | Convenient access to public transport service | 50.00 | 60.00 | 85.00 | 44 | 37.50 | 50.00 | 81.25 | 30.00 |
| 4 | Public transport quality and reliability | 52.50 | 79.97 | 31.00 | 30.1 | 34.62 | 76.87 | 1.54 | 0.15 |
| 5 | Traffic fatalities per 100,000 inhabitants | 2.10 | 7.75 | 6.33 | 14.9 | 94.00 | 77.87 | 81.91 | 57.34 |
| 6 | Affordability – travel costs as part of income | 18.20 | 5.71 | 11.10 | 12.82 | 53.33 | 92.98 | 75.87 | 70.41 |
| 7 | Operational costs of the public transport system | 55.40 | 51.95 | 102.40 | 93.8 | 21.83 | 19.57 | 52.55 | 46.93 |
| 8 | Investment in public transportation systems | 50.00 | 1.96 | 17.84 | 24.8 | 100.00 | 3.93 | 35.68 | 49.60 |
| 9 | Air quality (pm10) | 75.00 | 56.64 | 88.00 | 46 | 53.57 | 28.24 | 44.29 | 74.29 |
| 10 | Greenhouse gas emissions from transport | 0.53 | 0.33 | 0.57 | 0.63 | 80.73 | 88.16 | 79.27 | 77.09 |

The aggregate SUTI results for the four cities using formula 2 is shown in table 9. On the left the immediate scores for the cities; on the right, these are ranked according to performance.

**Table 9. SUTI score for 4 example cities [7]**

| City SUTI scores | | Ranked city SUTI scores | |
|---|---|---|---|
| Greater Jakarta | 50.01 | Greater Jakarta | 50.01 |
| Hanoi | 26.77 | Kathmandu | 41.91 |
| Kathmandu | 41.91 | Colombo | 32.70 |
| Colombo | 32.70 | Hanoi | 26.77 |

[6] The preliminary analysis is based on the data provided by the official expert from the four cities

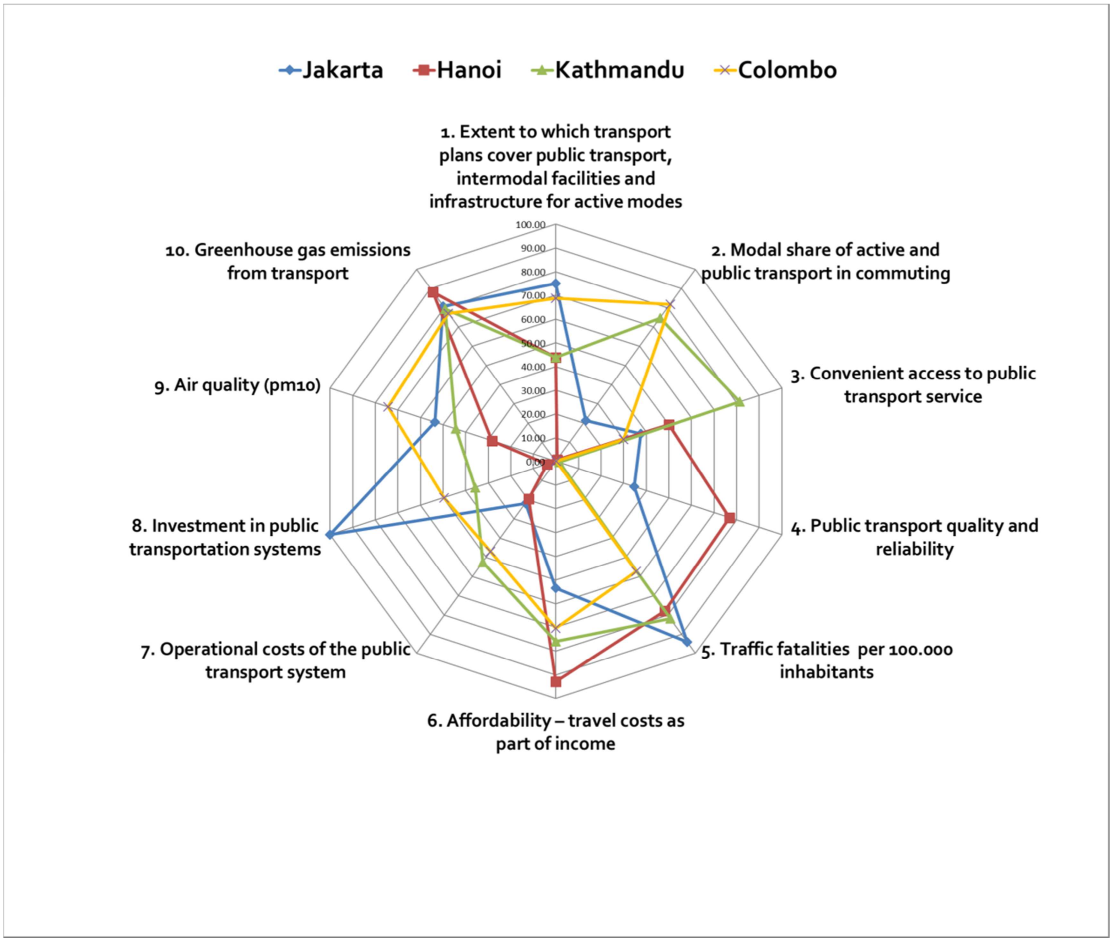
[7] The preliminary analysis is based on the data provided by the official expert from the four cities.

A basic observation is that all cities score middle or lower in the overall 0-100 scale. This is hardly surprising since the examples are developing cities. Moreover, there appears to be quite a spread in performance. This may reflect a spread in development levels as well as differences in regard to historical and geographical conditions, cultural factors, etc. It may also partly be a result of different plans and policies adopted in cities to influence transport performance and sustainability. Such variations cannot be discerned at the aggregate level.

Figure 2 illustrates the variation in performance of the selected cities at a more detailed level. The diagram allows comparing results at the disaggregated level per indicator. For example, is can be observed that the four cities have quite similar (and good) performance for indicator 10 (GHG emissions). This is could be indicative of still relatively low motorization among the developing Asian cities compared to developed cities. For most other indicators performance is much more diverse with both extremely high and extremely low scores. For example, indicator 4, quality and reliability of public transport where one city scores fairly, another somewhat less so, with the two remaining cities at the very bottom of the scale. Such variations may partly be a reflection of the real difference in experienced satisfaction among citizens but also partly the result of differences in data sources and methodologies.

Further analysis is required to possibly disentangle such factors. The purpose of SUTI is not to offer detailed explanations but to inspire cities to track and compare performance and to use such results to reflect on both data issues and policy needs and results. The still ongoing piloting phase of SUTI suggests that such fruitful reflections may indeed be inspired, at the individual city level as well as collectively among cities.

**Figure 2. Example illustrating performance across all indicators and four cities**



## CONCLUSIONS AND PERSPECTIVES

This paper has demonstrated the construction of a sustainable urban transport index reflecting urban transport-related SDGs relevant for Asian cities, based on literature review and expert consultations. A suitable framework was derived from basic sustainability dimensions, the SDG targets, and sustainable mobility strategies. The framework was used to identify a wide range of indicators in the literature as potentially relevant to measure for sustainable urban transport planning. After eliminating redundant, less relevant and infeasible indicators a shortlist of 20 remained. Conceptual and methodological criteria to review and select among these indicators were derived from literature and applied to the indicator set.

An Expert Group Meeting discussed the proposed indicators and the SUTI and found a need for further revisions. Two more indicators relating to public transport and the SDG 11.2 target on sustainable urban transport systems were added, and adjustments were made to some of the other indicators. In addition, the strict division of indicators into four domains, each forming a sub-index for the overall SUTI was abandoned. For each indicator, concise definitions were provided along with guidance on ways to collect data and report. The selected indicators were used to build an aggregate SUTI, partly inspired by methods used for deriving the Human Development Index, one of the most long-standing international composite indices. The calculation method is based on normalizing indicators using linear scaling along a range of min and max values for cities as goal posts. Where possible, these values were based on data for lowest and highest performance for existing cities as reported in international studies and literature. The indicators were given equal weight in the index since there is no general basis for differentiating among them. However, the SUTI does allow for installing a different weighting scheme, should such a scheme be agreed. The calculation method for the index was described and illustrated.

An Excel Data Sheet was developed, which aims to support the calculation of individual indicators, and the SUTI, as well as and to derive illustrations of performance for an individual city and for several cities. The SUTI calculations and results were exemplified using tentative data collected for four pilot cities. It has thus been demonstrated that SUTI is feasible in theory and in practice, although further analysis and review is required as to the scope for interpreting results, for improving the SUTI methodology further, and for potentially applying it more widely to cities in Asia. For most of the choices made in developing SUTI has involved a number of choices that could no doubt be reconsidered. This includes, for example, to adopt a more extensive indicator set around SUTI, or to use more sophisticated index calculation methodologies. The most important issue to consider may, however, be the constraints on the availability of suitable, regularly renewed data in cities across the Asian continent. Without data even the most sophisticated index is useless. The data need not only to be available but also comparable (based on similar methods) and feasible to regularly update. While the SUTI project did not have its focus to uncover the data availability challenges in full depth, it is encouraging to observe that all of the piloting cities were able to deliver data for all of the ten indicators and calculate the SUTI. Moreover, a number of other international initiatives are currently ongoing to define and collect indicators to monitor sustainable transport at the urban level, either as the main focus or as part of wider monitoring efforts. These include efforts by bodies such as UN-HABITAT, the International Association of Public Transport (UITP), the World Business Council for Sustainable Development, the World Council on City Data, The International Telecommunication Union, and the Global Covenant of Mayors. Also, the emerging World Bank-led initiative “Sustainable Mobility 4 all” may offer new avenues for reporting on sustainable transport on a global scale. Such efforts, combined with further development and application of SUTI are likely to help empower Asian cities to address significant challenges and better pursue sustainable urban transport policies in the future The SUTI would help measure progress in improving urban transport and especially contribute to achievement of SDG target 11.2

## ACKNOWLEDGEMENTS

The views expressed in this paper are those of the authors and do not necessarily reflect the view of the United Nations. The authors wish to thank the UNESCAP for supporting the development of the SUTI and the officials and experts from the four cities for providing preliminary data. Also thanks to several experts and national representatives offering valuable comments to draft versions of SUTI at two UN ESCAP events in 2016 and 2017. Special thanks to students Yannick Cornet and Christina Georgouli.

## REFERENCES

Ahangani, H., Gerrick., NW., and Atkinson-Palombo, C. (2015). The Relationship between Human Capital and Transportation. Sustainability for the US and Selected European countries. Submitted for presentation at the 95th Annual Meeting of the Transportation Research Board, January 2016.

Arthur D. Little (2014). The Future of Urban Mobility 2.0. Imperatives to shape extended mobility ecosystems of tomorrow. Arthur D. Little and UITP, Geneva, January 2014.

Banister, D. (2008). The sustainable mobility paradigm. Transport Policy, 15, pp. 73-80.
Castillo, H., and Pitfield, D.E. (2010). ELASTIC – A methodological framework for identifying and selecting sustainable transport indicators. Transportation Research Part D 15, pp.179–188.

Cornet, Y., and Gudmundsson, H. (2016). Building a Meta-Framework for Sustainable Transport Indicators – A Review of Selected Contributions, Transportation Research Record No. 2531, pp. 103-112.

De Gruyter, C., Currie, G., and Rose, G. (2017). Sustainability Measures of Urban Public Transport in Cities: A World Review and Focus on the Asia/Middle East Region. Sustainability, Vol. 9, No. 43, pp. 1-21.

ESCAP (2017) Assessment of Urban Transport Systems. Monograph Series on Sustainable and Inclusive Transport. United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) Bangkok, 2017. Available from http://www.unescap.org/publications/monograph-series-sustainable-and-inclusive-transport-assessment-urban-transport-systems.

EST Forum (2013). Bali Declaration on Vision Three ZEROs - Zero Congestion, Zero Pollution, and Zero Accidents towards Next Generation Transport Systems in Asia. Seventh Regional EST Forum in Asia, 23-25 April 2013, Bali, Indonesia. Available from http://www.uncrd.or.jp/.

Gillis, Dominique, Semanjski, Ivana, and Lauwers, Dirk (2016). How to Monitor Sustainable Mobility in Cities? Literature Review in the Frame of Creating a Set of Sustainable Mobility Indicators. Sustainability, 2016, Vol. No. 8, 29, pp. 1-30.

Gudmundsson, H, Hall, RP, Marsden, G and Zietsman, J (2016). Sustainable Transportation: Indicators, Frameworks, and Performance Management - Springer Texts in Business and Economics, Berlin.

Habitat (2016). SDG Goal 11 Monitoring Framework. A Guide to Assist National And Local Governments To Monitor and Report on SDG Goal 11 Indicators Monitoring Framework - Definitions – Metadata. UH-Habitat Technical Support. March 2016. Available from https://unhabitat.org/sdg-goal-11-monitoring-framework/.

IAEG-SDG (2016). Report of the Inter-Agency and Expert Group on Sustainable Development Goal Indicators. Statistical Commission Forty-seventh session 8-11 March 2016 Item 3 (a) of the provisional agenda E/CN.3/2016/2/Rev. United Nations Economic and Social Council, 19. February 2016.

Leda, H. (ed.) (2010). Sustainable Urban Transport in an Asian Context. cSUR-UT Series: Library for Sustainable Urban Regeneration Volume 9. Springer, Tokyo.

Jeon, Christy Mihyeon, and Amekudzi, Adjo (2005). Addressing Sustainability in Transportation Systems: Definitions, Indicators, and Metrics. Journal of Infrastructure Systems 11 (1), pp. 31–50.

Joumard, Robert, and Gudmundsson, Henrik (eds.) (2010). Indicators of Environmental Sustainability in Transport. : An interdisciplinary approach to methods. Recherches. Bron. Available from http://hal.archives-ouvertes.fr/hal-00492823/.

KOTI (2015).Sustainable Urban Transport Evaluation (SUTE) and the Way Forward (unpublished slides).

Martino, Angelo, De Stasio, Claudia, Tavasszy, Lori, and Chen, Ming (2010). A framework for Strategic Sustainability Assessment of European Transport Policies. 12th World Conference on Transport Research, July 11-15, 2010 – Lisbon, Portugal.

Nardo, M., Saisana, M., Saltelli, M., Tarantola, S., Hoffman, A. and Giovannini, E. (2005). Handbook on Constructing Composite Indicators: Methodology and User Guide. OECD, Paris. Available from http://www.oecd.org/std/42495745.pdf.

Rand Europe et al. (2004). Operationalizing Sustainable Transport and Mobility: System Diagram and Indicators. SUMMA. Deliverable 3 of Work package. 2 May 2004. Available from http://www.tmleuven.be/project/summa/summa-d3.pdf.

UNDP (2015). Training Material for Producing National Human Development Reports March 2015. UNDP Human Development Report Office. OCCASIONAL PAPER. Available from http://hdr.undp.org/sites/default/files/hdi_training.pdf.

UNESCAP (2016). Report of the Ministerial Conference on Transport on its third session. Economic and Social Commission for Asia and the Pacific Ministerial Conference on Transport Third session. Moscow, 5-9 December 2016.

UN-HLAG (2016). Mobilizing Sustainable Transport for Development. Analysis and Policy. Recommendations from the United Nations Secretary-General's High-Level Advisory Group on Sustainable Transport. United Nations, New York, 2016.

United Nations (2016). New Urban Agenda. Resolution adopted by the General Assembly on 23 December 2016. A RES 71/256. United Nations, New York.

WBCSD (2016). Methodology and indicator calculation method for sustainable urban mobility. Second Edition. Sustainable Mobility Project 2.0. The World Business Council for Sustainable Development, Geneva. Available from http://www.wbcsd.org/work-program/sector-projects/mobility.aspx.

WCED (1987). Our Common future. World Commission on Environment and Development, Oxford University Press, Oxford.

Zheng, Jason, Garrick, Norman W., Atkinson-Palombo, Carol, McCahill, Chris, and Marshall, Wesley (2013). Guidelines on developing performance metrics for evaluating transportation sustainability. Research in Transportation Business & Management, No. 7, pp. 4–13.

Zito, P., and Salvo, G. (2011). Toward an urban transport sustainability index: a European comparison. European Transport Research Review, Vol. 3, No. 4. pp. 179-195.