International Transport Forum

# Measuring Integration and Urban Sustainability with Indicators: Monitoring progress towards integrated public transport

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**Zsuzsanna Olofsson**
City of Trondheim
**Karin Brundell Freij**
WSP Sweden

OECD

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# Monitoring progress towards integrated public transport

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**Zsuzsanna Olofsson**
City of Trondheim, Trondheim, Norway

**Karin Brundell Freij**
WSP Sweden, Malmö, Sweden

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International Transport Forum
2 rue André Pascal
F-75775 Paris Cedex 16
contact@itf-oecd.org
www.itf-oecd.org

# ITF Discussion Papers

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# Abstract

This paper proposes a framework to monitor progress towards improved integration in public transport. The framework adapts some elements of Transport Sustainability Barometer (TSB) which is a tool to assess transport sustainability in Swedish cities. The suggested indicator set follows the complex hierarchy of layers in integration (Process, System, Quality and Use). The selected indicators allow progress to be monitored from two perspectives, objective evidence and citizens' perceptions. The proposed framework is only the first step towards a tool to monitor integration in public transport, and we provide recommendations to further develop a tool in consultation with its intended users.

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# Introduction

*Integration* is one of the most commonly used words in discussions about improvements of public transport system. Yet, the literature does not seem to offer any unanimous definition, neither of *integrated public transport*, nor of *integrated transport policy*. As a working definition, we consider an "integrated public transport system" as one with minimal barriers between different parts (such as trips, lines and modes) and one where travel is perceived as seamless, with potential synergies between parts able to be fully exploited by the user.

During the last decades, much effort has been put into making public transport *integrated*, and the concept integration has also become one of the most common elements in the vision for cities and transport systems as well as for transport policy. Decision makers, planners, transport operators all applied or tried to apply the principles of integration in their daily work. It is natural that following from this, an interest has risen to monitor the level of success in integration, and get information about how far a city has come in the process of integration.

There is an interesting parallel in the interest in measuring progress towards urban sustainability. During the last decade, several international research projects were completed with the aim of providing a comprehensive measuring method and tool for monitoring urban sustainability. Most of these measuring methods include at least some indicators that are also directly, or indirectly, related to aspects of integrated public transport systems.

The Transport Sustainability Barometer (TSB) is one such indicator framework: a tool to assess transport sustainability in Swedish cities. The tool was developed for and together with cities, in close collaboration with working groups from participating cities. A novel aspect of the measuring method presented in TSB is that the tool has two complementary perspectives: the objective and "subjective" perspectives. The current status concerning a specific aspect of sustainability is described with traditional traffic data – this is called the *objective* perspective. This view is then supplemented with a more subjective perspective, in which survey data is used to indicate how citizens, overall, perceive the situation regarding the same aspect.[1] The duality between the two perspectives provides an opportunity to identify relevant actions for political decision makers.

## Aim

We study whether the measuring philosophy of TSB can be applied or extended to measure the level of integration of a public transport system. Our intention is to provide a useful framework, and raise some central issues that have to be solved in the development of a measuring tool dedicated monitoring integration in public transport.

**To take a first step towards a measuring tool, we approach the following issues:**

- Provide a structure for the concept of integrated public transport
- Identify key terms and elements that can describe the benefits and main issues with integrated public transport
- Describe the central requirements for a useful indicator and monitoring system

- Analyse the transferability of TSB to the context of integrated public transport
- Provide a framework for monitoring of integrated public transport
- Suggest some measurable indicators that could be included in the framework
- Discuss the suggested framework and make recommendations for further work on the measuring tool.

## Working method and the structure of paper

The work started with a short literature study. The aim here was to identify the main features of *integrated urban transport* as it has been described in literature, the expected effects and benefits of integration (long term and short term), as well as the main actions by which public transport providers can improve the level of integration. Also, measuring methods and indicators of integration that have been suggested in literature were collected and analysed.

Based on the findings, a structure was suggested for how public transport integration can be understood and reflected in indicators. Specific concepts that related to expected benefits or relevant action fields were connected to the suggested structure. The section "Integrated public transport" describes this structure and concepts.

A description of some important issues regarding indicators and monitoring processes was formulated in the section "Monitoring and measuring progress with indicators". This section focuses on function, characteristics and requirements for indicators that should be taken into account in developing a set of indicators. Here, we use our experiences from the development of TSB as a case study.

So, to which extent could TSB be used (or extended) to monitor also the process towards more integrated public transport? Could the tool itself, or its basic philosophy, be adapted into a tool that focus integration? To investigate the potential for such a transfer, a thematic comparison was made between transport sustainability and integration in public transport. The section "Sustainability and integration" describes the comparison and assesses which parts of TSB could be transferable to the issue of public transport integration.

The framework is a synthesis of findings of literature and result of transferability analysis of TSB. The section "Indicator framework for integrated public transport" introduces a preliminary structure of indicators for measuring integration and gives some examples of potential indicators.

Developing a framework is only a first step towards a useful monitoring system. Recommendation for the remaining work is discussed briefly in the final section, as well as some identified strengths and weaknesses of the suggested framework.

## Limitations

This paper presents original research, prepared for discussions at an International Transport Forum Roundtable. The timeframe and resources available did not allow the full preparation of a complete tool for monitoring of integration in public transport. Neither did they allow us to validate the proposed structure, test it and analyse the results. The paper therefore only takes some important first steps of the process of creating a useful monitoring tool.

Public transport is subject to constant change. New travel modes and business models appear, making it increasingly difficult to identify a border between public and private transport. This paper, however, discusses integration in general terms that are not necessarily restricted to the current conventional types of public transport.

# Integrated public transport

In this section we describe the concept of integrated public transport. Integrated public transport is often mentioned as an important feature of a system for sustainable urban mobility. Despite the frequent use of the concept in vision making and goal setting, there does not seem to be any widely accepted and unequivocally published definition or measuring method of the level of integration in public transport. Our study does not aim to produce such a general definition.

The main purpose of this paper is to discuss the measurement and monitoring of integration. In this section, the aim is twofold: to establish a terminology for the discussion in this paper and to identify concepts that can be used to monitor integration. Concepts should cover three dimensions: *Where* is integration observable (sectors, layers)? *Why* is integration desirable (aim, impacts)? *What* can be done to integrate public transport (actions, elements)? We therefore need to collect information about the characteristics of a (well) integrated public transport system, the effects that decision makers expect to achieve by integrating public transport, and the different action fields within which measures can be taken to increase integration, and – potentially – prioritise between these.

## System integration, integrated planning and user-perceived quality

The public transport system can be considered to consist of different *parts*, for example: trips, lines and modes. The motive behind integration is that it is assumed that quality for customers would be improved if barriers between the “parts” are removed, and synergies generated through coordination between them (May et al 2006). This implies that integration could be conducted at different levels – between trips, lines or modes.

A starting point for our work is that integration of public transport should not be regarded as an overall aim in itself. Rather, it is one of several ways by which decision makers, planners and public transport providers can improve the public transport system, so as to offer better travel options for (potential) users, at lower cost for passengers and tax payers. Neither are integration and seamlessness, in themselves, sufficient conditions for a “good” public transport system. For example, if timetable frequency is too low, public transport will not attract users, however ‘seamless’ the trips may be.

Despite this, there is reason to focus and monitor integration specifically. In systems that have previously been planned in silos, it will be possible to improve quality by removing barriers, and/or exploit positive synergies (May et al 2006). Often, this type of improvement will also be cost-efficient compared to other measures (Navarrete and Ortuzar 2013). Support for basically the same type of efforts is motivated somewhat differently by NEA (2003), who apply micro-economic terminology and explain integration as an intervention to deal with market failures and network effects, in order to optimise welfare.

Thus, the reason that we strive for improved travel opportunities is that they can improve quality of life for individuals, and generate economic value for society as a whole. In the end, the improvement may also result in indirect (“external”) benefits to society by, for example, less car driving, congestion and air pollution. However, most of the intended benefits will only occur if integration efforts contribute to **perceived** improvement of service quality, reflected in behavioural change and increased ridership. Therefore, if we want to monitor how successful the integration process is, we cannot limit our observations to hard system characteristics, but have to involve also how those changes are assessed by users, and reflected in use.

Also in the other end of the chain, the “origin” of integration, there is reason to extend our monitoring efforts beyond observable characteristics of the public transport system itself. NEA (2003) stresses that integration is not a state of the system, but rather a dynamic process driven by the constantly changing mobility. For the same reason, according to May et al. (2006), integration cannot be regarded as a final outcome, or as one of the "agreed objectives of transport policy". Rather, according to the authors, it is better to think of integration as a desirable way of working, as a method, or process characteristic of decision making and planning.

## Layers of integration

Thus, integration can be regarded as occurring at different layers (Figure 1).

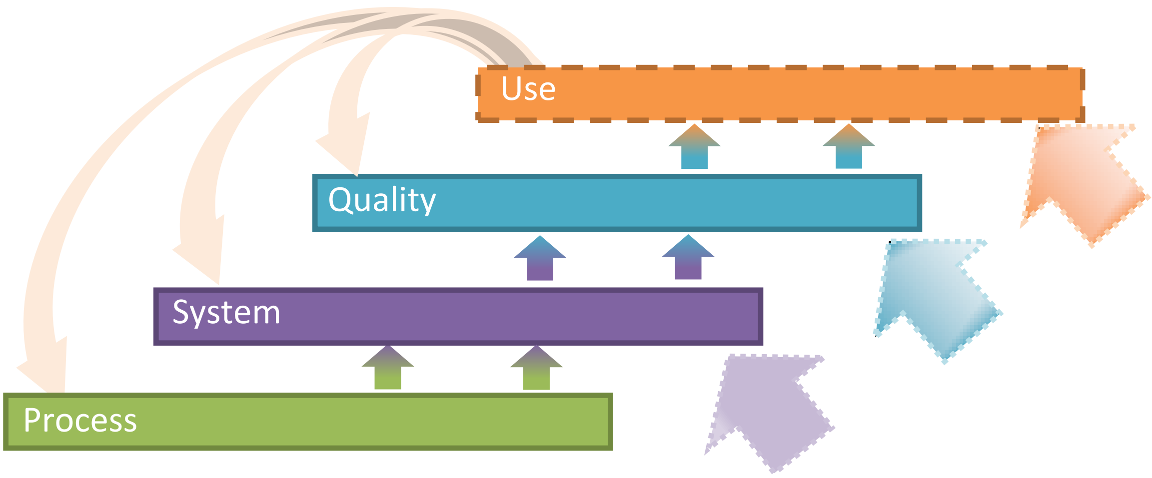
**Process:** Firstly, public transport will only become integrated if planning processes and organisations remove silo-thinking and apply a system-oriented approach.

**System:** Then, to make a difference, the integrated process has to produce concrete results – remove barriers and establish synergies within the public transport system. (Such barriers and synergies can apply to different aspects of the system: network, traffic or overall service.)

**Quality:** These "improvements" must be relevant for users, in terms of their preferences, as well as where they want to go, and which other travel options are available for them.

**Use:** For some expected societal benefits to arise (reduced negative externalities from car travel), we require also that the changes affect use, such as modal choice and ridership.

Figure 1. **A suggested structure for integration in public transport**




In this chain, there are casual linkages between the layers, but also many other factors that affect overall quality for users, and use. Also, downstream in the chain, it becomes increasingly difficult to separate the effects of integration from the effects of other measures that may be taken. We may be able to identify the specific integration aspects of processes and systems, but user quality is an indivisible property of the system as a whole.

From a monitoring perspective it is important to acknowledge also the influence of other, uncontrolled, factors in the process from action to intended benefits. As a consequence, indicators and monitoring framework has to be selected as a balance between (i) the wish to measure whether we succeed with our aims or not (quality and use), and (ii) the wish to focus on what we control (process and system).

An often neglected aspect of integration (that also applies to public transport policy in general) is the feedback loops that are indicated in Figure 1. When public transport ridership increases, and passengers use the whole system for more integrated trips, this will push providers towards an even more integrated offer. This is partly because of direct economies of scale (the "Mohring effect" (Mohring, 1972)), but also because public transport users themselves play an important role in pushing customer demands, and also market public transport travel and provide information about public transport options to other potential passengers.

## Elements of an integrated public transport system

In the previous section we have presented how integration is expressed in different layers, from working processes, over the concrete features of the public transport system, to provided transport quality and public transport ridership. To be able to "monitor integration", and show how we progress towards our vision of a fully integrated system, we need a clearer picture of those elements of each layer that can be affected by integration measures.

Concerning the decision making and planning **processes**, good integration can be demonstrated in several ways. It can show in organisational patterns that link operation of different modes closely together (formal cooperation), or in intense flow of information and communication between different organisations (informal cooperation) (Chisholm, 1989). Another sign of integration in this layer could be the amount of resources that are allocated to integration and cooperation.

Regarding how integration is reflected in concrete features of the **public transport system**, we have identified three different groups of elements in the literature:

One group of descriptions relate to the hardware, the public transport *network*, and how public transport infrastructure is designed and located. Another group of descriptions focus on integration aspects of *traffic*, whereas a third group of descriptions relate to the integration of other, softer, aspects of the overall offer. We use the concept *service* here for these other aspects (although 'service' may, in some literature, refer also to traffic and timetables).

An example of the *network* perspective is Murray (2015) who describes the integrated transport system as a coherent system without unnecessary redundancies, clear sharing between network elements, hierarchical feeding system, routing suitable for trips and tailor-made interchange points. A concrete example of network characteristics that indicate integration is the existence of multimodal terminals and shared stops (Solecka and Zak, 2014). Hierarchically organised networks, with a split between core modes which are fed by complementary modes (Potter and Skinner 2000) is another example,

With an integrated network and infrastructure, it will become easier for providers to offer an integrated *traffic*, with coordinated timetables (Solecka and Zak, 2014) that reduce waiting times and allow convenient transfers.

The potential benefits of such a system could be further improved if seamless travel is offered as a coherent multidimensional *service* (providing for example comprehensive information, clear connections, and reasonable and simple fare and ticketing systems) (PROSPECT, 2003). Such high levels of cooperation in all areas cannot be achieved without a combination of technical prerequisites and close cooperation between different operators and organisations.

An integrated transport system operates as a seamless entity, with all transport modes involved and complete each other, and this is made for the benefit of the fare paying customer. The effectiveness of the efforts taken to make the public transport system integrated will therefore be first determined by the extent to which the improvements affect overall **perceived quality**. User preferences and activity patterns are vital to understand and evaluate the level of integration. For example, the agreement between the public transport system and the geographical distribution of trip origins and destinations (land use), and also the competitiveness of public transport standard in relation to the standard of other competing modes (cars in particular), are important to assess overall quality.

Only if the public transport system can offer a relatively seamless 'door-to-door' transport, which is perceived as relevant, pleasant, comfortable and simple-to-use will its competiveness with other individual traveling modes increase, and result in increased **use** and ridership. However, many of the factors that affect ridership are beyond the control of public transport providers.

## Impacts of integrated public transport

As has been shown above, integration occurs within different fields ("layers"), and there is reason to evaluate progress in each of them. Integration is also a complex process, seeking to achieve several – potentially conflicting – outcomes.

Literature shows that increased integration can be expected to give several different observable, and potentially measureable, impacts within each of the four layers (Goldman et al. 2014; UITP 2011; Solecka and Zak 2014; Dadson et al. 2011; UITP 2016; Prospect 2003). It is therefore impossible to evaluate the success or the progress of integration with only one indicator. Nevertheless, as far as possible it would be desirable to reduce the number of dimensions involved, and present combined measurements of integration that weigh different aspects together. When relevant, the weights should preferably be determined so that the combined measure reflects user preferences.

In the structure we suggest for monitoring, we use comprehensive concepts to represent the combined impacts within each layer.

To describe integration of the **process**, we use the term ***cooperation***. Here, at this stage, we use the term in an intuitive meaning, without suggesting any formal definition or set of weights.

For the level of integration of the public transport **system** we use the term ***connectivity***. The term (inter)connectivity has previously been used by several authors to describe the level of integration regarding both lines and modes of the overall public transport system**.** Some authors define connectivity as relating specifically to the quality of transfers (for example Hadas and Ranjitkar, 2012). Chowdry et al (2014) however, present a very comprehensive measure of connectivity**,** combining a wide range of important factors. They show that the combined index can be computed from data publically available from Google Transit. In their paper, factors such as travel time, number of transfers, walking distance etcetera are combined. Applied weights are based on average user preferences, and could therefore be said to reflect generalised cost. However, the comprehensive assessment – connectivity – is nevertheless restricted to a description of the system characteristics, without any consideration to the spatial distribution of travel, demography or the quality of competing modes. This is what, in our opinion, makes their measure an indicator of "system" integration, rather than "quality".

To describe how integration is affecting the overall **quality** of travel for citizens, we use the term ***accessibility.*** A comprehensive measure for overall accessibility is the logsum index applied by Niemeier, D.A (1997). The logsum evaluates the effort (measured by generalised cost) it takes to travel in between an origin and destination, in a way that accounts for both the attractiveness of different travel destinations, the availability of competing travel options and the quality of these options. Obviously, accessibility is affected by many things that are not related to "integration" (see the thicker arrows in Figure 1). Nevertheless, actions to improve integration will not provide value to passengers if it does not improve overall accessibility (i.e. reducing the effort of travel).

To describe **use**, data on ***ridership*** is typically available and relevant. As stated above, it is however important to acknowledge that data on ridership is influenced by many other things than the current level of integration.

## Actions and activities that improve integration

In Table 1 we connect various measures that have been proposed in literature (Murrau et al. 2015; Solecka and Zak 2014; Goldman et al. 2014; SPUTNIC 2009; Kellerman and Degand 2003; Potter and Skinner 2000; May et al. 2006; Yiu; 2005) to the layers in which integration can occur. The first column of Table 1 summarises the most frequently mentioned fields of action and concrete measures. Ticks in the table indicate how measures are related to the layers identified in Figure 1 above. As the table shows, there is a wide range of potential types of integration measures. These activities provide benefits on different elements of the layers of integration and the procedures necessary to carry out integration behind these measures involve many stakeholders.

Table 1. **Actions for integration**

| | **Layers of integration** | | | |
|---|---|---|---|---|
| **Actions** | Process | System | Quality | Use |
| Information (integrated passenger information, travel planners) | | ✓ | | |
| Fare (user-friendly ticketing, integrated tariff, city tickets) | ✓ | | | |
| Organisation (coordinated time tables) | | ✓ | | |
| Institutional (integrated routes, shared stops) | | ✓ | | |
| Planning (policy measures to change travel habits) | ✓ | | | |
| Network (complementing modes, seamless travel) | | ✓ | | |
| Accessibility (Transit oriented land use planning) | | | ✓ | |
| Connectivity (interconnecting networks and modes ) | | ✓ | | |
| Individual and public transport modes (choice of travel modes) | | | ✓ | |
| Social (turning waiting time into an asset, safety and security at transfers) | | | ✓ | |

The table shows also that no integration measures are seen as affecting use directly. Rather, increased use will be the outcome of measures that are taken to make processes or the system itself more integrated if these are also seen by the user to improve quality.

# Monitoring and measuring progress with indicators

In any complex process, there is a natural interest to be able to measure progress towards the overall objectives with a multidimensional set of indicators. This section gives a short overview of indicator measurements in general, as well as the measuring philosophy and method applied for the development in a specific case – the Transport Sustainability Barometer (TSB) (Toth-Szabo et al. 2011) – and the general lessons learned from that process.

## Developing indicators

Evaluating the performance of a complex system or a process that varies in time, such as a transport system or the level of sustainability, we need a reliable measuring method. The largest challenge with developing a measuring method is defining a set of variables to be measured – called indicators. A secondary requirement is a reference point that allows the comparison of the result with some baseline measurement of the state of the system. Further, it is vital to understand the concepts and use them appropriately to be able to interpret and communicate results properly.

The OECD (2003) defined the following terms related to monitoring a process through measurements:

*Parameter:* a property that is measured or observed.

*Indicator*: a parameter, or a value derived from parameters, which points to, provides information about, describes the state of a phenomenon, or environment, or area, with a significance extending beyond that directly associated with a parameter value.

*Index*: a set of aggregated or weighted parameters or indicators.

Two major functions of indicators were pointed out by OECD (2003):

*Reduce the number of measurements* and parameters that would be required to give an exact presentation of a situation.

*Simplify the communication process*. The selected indicators may be simplified or adapted to the user's needs, but should always be regarded as an expression of "the best knowledge available" also from a scientific perspective.

There are various types of indicators, grouped by the sort of information they provide, including:

*Quantitative data* consists of numerically measurable information.

*Qualitative data* can consist of words, picture, observational data etc.

*Ratio indicators* are indicators for which the measurements are normalised to facilitate comparisons, such as per-year, per-capita, per vehicle-year, per unit of money (Litman, 2016).

*Relative indicators* show trends over time or comparisons (Litman, 2016) Also indicators that describe the result of an action related to a goal, based on the same "how close / how far from" principle are also included in this group, but they can also be called state indicators or warning indicators.

The most important requirements for the selection of a useful indicator were summarised by Sustainable Measures (2010) as:

- Relevance
- Easy to understand

- Reliability
- Based on accessible data.

To be able to guide a multi-level decision making process with appropriate indicators, it is important to adapt to the inherent hierarchy within the process. For example, municipal officials who make detailed decisions about roadway design would need more detailed feedback, than politicians who decide about distribution of resources on a strategic level. Several categories can be defined to form a hierarchy of indicators in a selected indicator set, where “lower” levels can be used to provide more detailed understanding about the development, whereas “higher” levels gives a more aggregate representation of the same processes (Litman, 2016).

## Case study: the Transport Sustainability Barometer

Sustainable urban mobility is a complex process with many stakeholders who work together towards a shared ambition. Several evaluation methods and indicator systems have been developed in recent years to measure sustainability in transport, e.g. Ecomobility SHIFT (Carreno et al. 2013), QUEST and ADVANCE (Voet et al. 2013). TSB is one of them.

The Transport Sustainability Barometer (TSB) is a tool developed as part of the Swedish research program called HASTA (Sustainable Attractive City).[2] The aim of the work was to develop a measuring tool that could help Swedish municipalities to monitor and evaluate their work to promote transport sustainability. The tool was developed for and together with Swedish cities. The close cooperation between the research team and working groups from nine cities including planners, officers, and decision makers was vital for the outcome. The whole working process with the cities, the selection of indicator, formation of the framework and the design of the tool itself are described in detail by Toth-Szabo et al. (2011) and Olofsson et al (2016).

One important finding from the initial literature study was that any measuring method will be a reflection of a specific understanding of sustainability. As Swedish cities were the main target group for the research, identifying common features of each group’s understanding of sustainability was an essential first step of the work. For practical reasons, the nine cities that participated in the project are all located in the southern part of Sweden (within reasonable distance from Lund, where the research team was located). Other than that, participating cities may be regarded as a reasonably representative sample of Swedish municipalities, varying in size, economic status, political commitment for sustainability issues and how successful they are in that work. After several workshops with decision makers and officers, it was agreed that the applied framework should: a) reflect the multi-dimensional nature of sustainability; b) focus on the type of issues that are relevant for municipal transport planning (i.e. not national or regional issues); c) include citizens’ perceptions as well as the intentions of politicians; d) be easily available for cities (and use existing data as much as possible); and e) be grounded in the agreed objectives for national transport policy (Olofsson et al 2016).

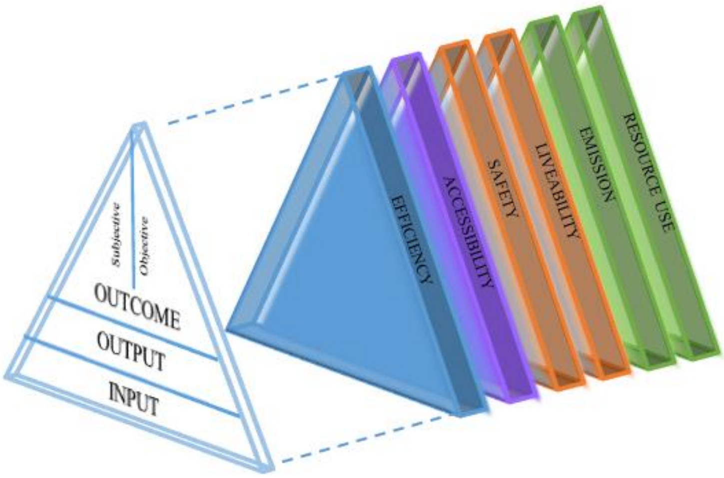
The framework developed for the TSB has a two-dimensional main structure of indicators (Figure 2).

Box 1. **The structure of the TSB indicator framework**

The horizontal dimension of the TSB indicator framework represents the three main fields that are often used to describe the consequences of transport, i.e., Economic, Social, and Environmental effects (ECMT, 2004). At the same time, the horizontal dimension reflects sustainability aspects identified by Litman (2009), e.g., liveability and safety. In total, six groups of indicators were defined:

- Efficiency (Economic)
- Accessibility (Economic and Social)
- Safety (Social)
- Liveability (Social)
- Emissions (Environmental)
- Resource use (Environmental).

Figure 2. **Hierarchical structure of the indicator framework**




The vertical dimension represents the transport system's well-defined hierarchical structure, ranging from political vision making at the top, down to the daily decisions by operational staff at the bottom. To summarise the vertical dimension:

- *Outcome* indicators (at the top) generally relate to the overall aim(s) of transport sustainability. Example: *Injury risk per passenger km travelled.* Among the outcome indicators we differentiate between those that reflect the objectively measurable status regarding sustainability and those that reflect how citizens perceive it.
    - *Objective* indicators are based on measured, quantitative information.
    - *Subjective* indicators reflect people's perception of and satisfaction with sustainability-related issues.
- *Output* indicators are indirect or intermediate indicators that show the direct result of the measures taken (*Input indicators*), which in turn influence accomplishment of overall aims (*Outcomes*). Example: *Percentage of motor vehicles above speed limit*.
- *Input* indicators reflect potential measures that can be implemented in order to improve Output or Outcome - that is to fulfil the goals and visions of the city. Example: *Percentage of crossing points for pedestrians meeting agreed design standards*

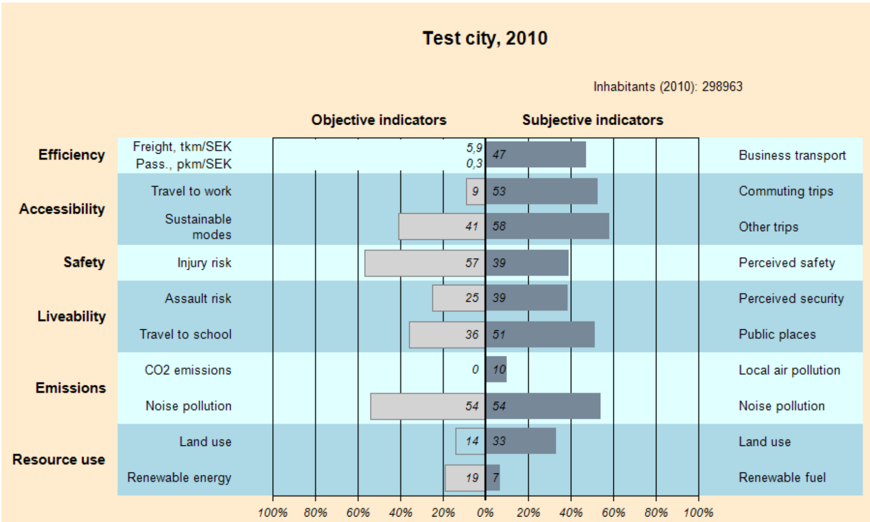
Source: Olofsson et al (2016).

Indicators were selected in two steps. First, the research team prepared a long list of potential indicators based on indicators from the scientific literature (published before 2010). The long list was discussed and improved further together with the working groups. The final selection of indicators was municipalities either having the required data, or their ability to collect this data. Together, the indicators selected represented all six aspects (horizontal dimension) and all three hierarchical indicator levels (vertical dimension). In all, there were 19 Outcome indicators, 22 Output indicators and 42 Input indicators in the final set.

Once the set of indicators was agreed, data collection started. The aim was to formalise a standardised, validated methodology for data collection to establish a consistent database. Although the indicators were selected based in part on data availability, the municipalities realised that the selected indicator structure required much more work with data collection than cities could handle on a regular basis. Consequently, researchers and the cities agreed that continued development should focus on outcome indicators only, since these indicators are at the same time connected to the visions of cities, and linked to existing data collection. Data for objective indicators were collected from official databases, while data for subjective indicators were collected from surveys.

Box 2. **TSB: Visualisation of the sustainability level**

Figure 3. **Example TSB indicator scorecard**




The TSB seeks to monitor the gap between the base year and a desired goal in each measured aspect of sustainability.

For the majority of the objective indicators, targets (100% fulfilment) could be defined from Swedish national targets and local transport strategies and visions, e.g. Vision Zero for traffic safety, national CO2 reduction targets, and the ratio between travel times for different transport modes. Each indicator gets its score by relating the objectively measured value to the desired target (100% fulfilment) for that specific indicator.

For the subjective indicators, the researchers and the participating cities agreed to regard maximum satisfaction among the residents as the desired target (100% satisfaction). The higher the value, the more positive the residents' assessments of the transport system.

Both the objective indicators and the subjective indicators are displayed in bar charts. The length of the bar shows the relative value (percentage) for that indicator (Figure 3). The higher the value, the closer the city is to achieving its goal of sustainable transport.

*Source*: Olofsson et al. 2016

Regarding visualisation of results, researchers and the cities agreed that the results should be presented in a graphic form that was simple, easy to understand, with a clear relation to the main indicator groups, and an obvious distinction between subjective and objective results.

In addition to regular monitoring (for example on a yearly basis), the TSB tool can also be used either to compare the speed of development (changes of the indicator levels between successive years), or to recalculate the indicator value as a consequence of changes of the desired target level (since all values are scaled relative to the target).

The last phase of the research provided an analysis of how changes in indicator values, (and combinations of such changes for different indicators) could be interpreted, in terms of which new decisions and priorities the results would propose.

## Lessons from the development of TSB

The main aim of the project was to develop a tool for Swedish municipalities to use to assess transport sustainability performance. Other than the tool itself, the project also provided experience in overcoming gaps between different working methods, different demands on information, different responsibilities and different priorities among and within municipalities. The most important lessons learned during the project were:

*Clear objectives:* Developing a measuring tool is a long and creative process. It was vital to keep the project aim alive during the long discussions and ensure that (necessary) compromises within the working group do not jeopardise the overall objectives of the exercise.

*Cooperation:* The collaboration between the cities and the research team was the main driving force behind the whole process. To retain a focus on opportunities instead of barriers was one of the main challenges.

*Communication:* The only tool that could overcome difficulties. As with other tools it takes time and energy to use it effectively.

*Complexity:* The tool was designed to simplify and clearly visualise the results of a complex process for communication to potentially decision makers, civil servants and inhabitants. Nevertheless, this clarity requires a relatively deep understanding of the concept of sustainability and the data underlying the indicators.

*Data availability:* The availability, structure and quality of relevant data varied substantially between the cities. To be able to use the same structure for all cities, the structure had in each case to be adapted to the weakest link regarding data availability.

*Data collection:* The cities have only limited possibilities to extend or change their existing data collection. Where there was a need to introduce new methods or new variables, careful preparation and detailed instructions for data collection, frequency and processing were required to ensure quality data is collected.

*Monitoring:* To be able to introduce and continue systematic data collection, municipalities need to allocate human and financial resources on an on-going basis.

# Sustainability and integration – similarities and differences from a monitoring perspective

Many aspects are common to transport sustainability and transport integration. A comparison focusing on the main similarities (and differences) between the two concepts can help us to understand to what extent the measuring philosophy of TSB can be extended or adapted to monitor improvements related to integration.

## Similarities and differences

A comparison is made for the following aspects:

- **Conceptual**
- **Vision and measuring philosophy**
- **Framework**
- **Indicators**
- **Data collection**
- **Interpretation of results**
- **Visualisation**

The definition of sustainable transport used in the TSB is "a sustainable transport system is one that achieves the best possible balance between the social – environmental – economic dimensions of transport" (Toth-Szabo et al. 2011). From the **conceptual view**, the biggest differences between sustainability and integration of public transport is that sustainability can be regarded as a final overall objective while integration can only be a means to contribute to the achievement of other goals. Another important difference is the range of stakeholders and subsectors within transport that are involved (for sustainability: all; for integration: public transport specifically). At the same time, there are many similarities between the processes by which sustainability and integration are improved. Public transport integration and transport sustainability both require long-term co-operation towards a common vision, despite partly opposing interests, based on a willingness to make balanced changes that are sufficiently acceptable for all stakeholders.

In developing the TSB, a choice made by the participating municipalities was that the measuring method should "evaluate neither the vision [of each city] nor the vision's effect on the cities' transport system" (Toth-Szabo et al. 2011). Instead, TSB takes the vision or target of each city and describe *progress* towards that target for each city. To emphasise this objective *progress indicators* are defined (rather than performance indicators). Concerning the **vision view**, sustainability objectives tend to be more closely specified than integration objectives, which can be vague. However, motivations for monitoring sustainability and integration are similar: evaluating the effects of measures taken. Monitoring allows governments to (i) identify whether the city is approaching its vision, (ii) identify a priority list for actions that could reduce problems, or (iii) create an action plan and determine an optimal level of action.

Tools that aim to measure and monitor sustainable transport typically apply relatively complex frameworks. TSB was designed as a two-dimensional framework. The vertical dimension represents the transport system's hierarchical structure; the horizontal dimension represents various aspects of sustainability (Box 1; Olofsson et al. 2016). Integration in public transport, too, can be said to reflect a hierarchy, but a different one. The internal hierarchy of public transport providers is related to company structures, and co-operation between public transport providers and operators is inherently limited by its potential economic consequences.

Complex processes, like sustainability in urban mobility, are often described by progress indicators. The concepts which are used as indicators, (e.g. effectiveness, accessibility, quality of life) are typically neither well defined nor measurable in a standardised and simple manner. Rather they are specific for the process that we want to measure. In developing the TSB, it was a request from the cities that the terminology for the indicators should be based on the words used in political discussions rather than being limited to the stricter concepts used in technical discussions. The aim was to develop a common understanding between politicians and municipal officers concerning the meaning, context and relation between measures and their effects. Since any integration measurement framework would also need to be commonly understood by diverse actors, the use of simpler terminology also.

There are two more circumstances influencing profoundly the work with the indicators: (1) the need to create a common understanding of the problem among different stakeholders and (2) expectations related to the visualisation of the results. These points may not relate directly to "transferability" as such, but they play an important role for the final selection of indicators.

- The core of the sustainable mobility is "common understanding". In the creation of TSB, it was vital for Swedish cities to see how citizens perceive the changes that the city goes through, and the actions that decision makers take, to approach a more sustainable transport system. In public transport, too, the users' perceptions and understanding are crucial. This makes it tempting to measure changes in both objective conditions and citizens perceptions, related to efforts that are taken to make public transport integrated.
- Sustainability, just like other abstract concepts, is difficult to visualise. Difficulties with reference points, differences between units and different rates of change made it a challenge to summarise the multidimensional results in TSB in one common diagram. The overall objective was simplicity and transparency, allowing for different kinds of stakeholders to understand the results. Since both sustainability and public transport integration are complex processes, we will probably face the same challenges when we try to comprehensively visualise the results of a measurement of public transport integration, as we did with sustainable transport.

## Conclusion about transferability

Both integration and sustainability is a process, even though sustainability is a much wider, more complex process, which relates to basically any mobility issue.

The **measuring philosophy of TSB** (take the vision as target, and present results in relation to complete fulfilment) is **transferable in principle**. The problem lies in setting the vision and formulating the targets.

The two-dimensional framework of TSB is not fully appropriate for the measurement of public transport integration. One of the problems is that in TSB, the horizontal dimension represents a split into very different types of effects, which are potentially uncorrelated. In public transport, we have the "layers" of integration (Process - System – Quality – Use) that are instead strongly related each other.

The vertical dimension of TSB is motivated by the need to bridge a wide gap between (i) scope and goals at the strategic level and the (ii) objectives that relate to specific measures. In public transport integration system providers are typically organised in companies or divisions, so the gap is much smaller between strategic planning and concrete measures that are taken. Instead, the more challenging gap that the integration seeks to bridge is between (sub) companies – for example between different lines or public transport modes. This leads us to the conclusion that the outcome-output-input structure may be used for integration, too**.** However the focus of interest for sustainability will be more on the outcome level (since sustainability is an objective), while the focus of interest for integration will be more on the input level (since integration is a means to an end).

The structure in which one **progress indicator** is selected per aspect, and that similar indicators are chosen for assessing objective conditions and citizens' perceptions, is relevant also for monitoring of public transport integration.

Indicators that are selected to measure public transport integration, in a framework similar to TSB, should as far as possible be simple, unequivocal and well defined to allow for comparable and repeated measurements over an extended period.

An integrated public transport system is a feature that is expected of a sustainable transport system. Therefore, most tools for measuring sustainable mobility do include indicators that are related to public transport and, perhaps only implicitly, its integration. Many different indicators for sustainable transport have been suggested in literature. They can serve as a long list for discussions about which indicators could be used to measure integration. The detailed definition, measurement units, content of information and possible overlap of information has to be checked carefully with the client (target group) before the final selection of indicators.

How the results from a measuring process can be visualised is often discussed jointly with the development of the measuring tool. For measurements of public transport integration, the layout of TSB (and other tools) is a good starting point for the design and layout, though this would clearly need to be adapted to the methods and indicators that are selected for measurement, and the needs and demands expressed by the target audience for the results.

## Monitoring integrated public transport

In the previous section we analysed the elements of the Transport Sustainability Barometer (TSB) that might be transferable to monitoring public transport integration. In earlier sections of this paper, we have also described and provided a structure for *where* integrated public transport can be identified, the rationale for *why* integration is performed, and *what* is typically done to improve the level of integration. In this section, we suggest a framework in which those building blocks are combined into a structure for monitoring public transport integration.

Measuring tools are typically composed of a set of multiple indicators to capture the required information. Many different issues are comprised in what is often called the tool's "framework": The objective(s) for selecting indicators, the decision on how to combine different types of indicators, how many indicators to include, and how the different indicators relate to each other together define the framework.

We propose the following steps to create a framework for integration in public transport:

- Identify building blocks and its hierarchy
- Select comprehensive performance indicators
- Identify sub-indicators representing both objective conditions and citizens' perceptions

- Define an overall framework

The **building blocks** of the framework should reflect the main issues related to the integration of public transport that we have identified. In the second section, we suggested using four identified layers in which integration can be reflected in a logical hierarchy (see Figure 1) as one of the frameworks' dimensions: Process, System, Quality and Use. Each layer is considered to influence all others, which is similar to the input–output–outcome relation in TSB.

However, there are also significant differences in our proposed framework for integrated public transport compared with the TSB. We have chosen here to represent the hierarchy between the layers of integration with an upside down pyramid with widening sides (Figure 4). While the triangle in the TSB framework represents the number of indicators on each level, here the broad top here indicates that many factors beyond integration influence the use of public transport. The narrow base indicates that measurements of process and public transport system can be limited specifically to integration aspects. There is no specific part of "use" that could be explained by the level of integration. Neither would it be meaningful to separate out "integration aspects" of *accessibility*, and analyse them specifically. In contrast, *cooperation* in planning and processes, and *connectivity* between lines and modes, are aspects that do relate specifically to integration. In this sense the bottom layer is more narrow (fewer aspects are included) than the top.

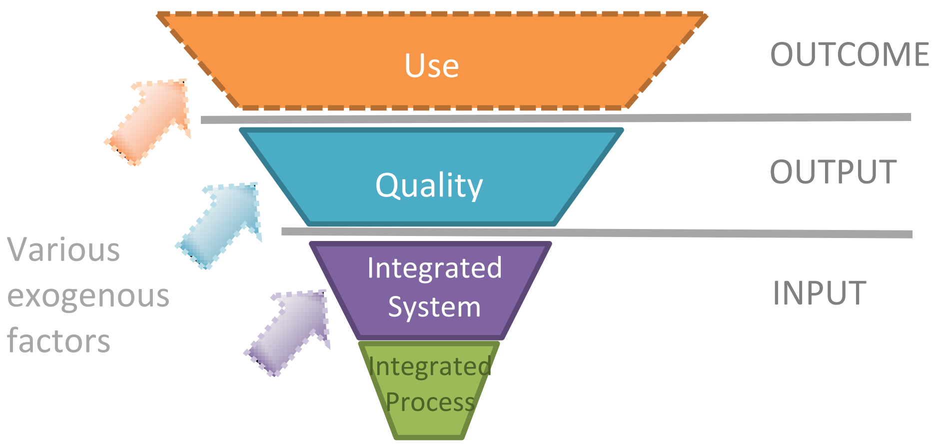
Mapping the structure of layers that we propose for integration to the hierarchical levels that were used in TSB, we suggest the following labels:

***Outcome*** level – related to the overall achievement of policy objectives, but with a less clear relation to measures and actions. This can be measured by indicators of the ***use*** of public transport.

***Output*** level – reflects the concrete results of all measures taken. This can be measured by indicators of system ***quality*** as it is perceived by users, when they consider also their travel needs and alternative travel options.

***Input* level – reflects the measures that involved agents can take to improve integration. Here we place both *process* and *system* layers. Most of the concrete measures are designed to modify either the system properties, or the process by which they are decided (Table 1).**

Figure 4. **A suggested hierarchy for aspects of integration in public transport**




The next step would be to select and define a comprehensive **progress indicator** for each level. We describe the levels from bottom to top.

To describe the level of integration in the *processes*, we use the concept *cooperation*. In measuring cooperation, we can draw from indicator sets that were developed to capture process related aspects of sustainability. No such aspects were included directly in TSB, but for example ADVANCE (i.e. "integrated planning approach" and "multimodal approach" in Voet et al. 2013) and Ecomobilty SHIFT (i.e. "collaboration across departments" in Carreno et al. 2013) did develop indicators as well as evaluation methods to describe the work in and between organisations, public participation and staff resources. The achievements made in those projects could serve as a good starting point for discussions with relevant target groups, on how we should best define a measurable quantity that could describe the level of cooperation between potential public transport "silos".

To describe the level of integration in the system, we suggest the concept of *connectivity*. To define a relevant indicator for system connectivity, an excellent starting point is provided by Chowdhury et al (2014). They compute an index that reflects the combined quality of all possible public transport trip relations, including potential transfers, according to the principles of generalised cost, and aggregate those over origin-destination trip pairs. If, for example, waiting time is included in the measure, this indicator would be sensitive to efforts made to reduce barriers in the system by the coordination of timetables).

To indicate the impacts of improved integration (and other efforts) on *quality*, on the output level, we suggest *accessibility*. Accessibility is a concept with a long history in transport geography, which aims to aggregate the overall effort required to reach attractive destinations, without putting unnecessary weight on travel options to less attractive destinations (Handy & Niemeier, 1997; Niemeier, 1997). The difference between connectivity and accessibility in our terminology is that the connectivity indicator is supply oriented while accessibility accounts for actual demand for trips.[3] Many different accessibility indices have been suggested in literature. They differ in how they combine i) travel effort to each destination (generalised cost) and ii) the attractiveness of reaching the same destinations.

Finally, for the outcome level, we suggest that travel behaviour and *Use* of public transport should be reflected in an overall indicator for *ridership*. Many different data collection methods for ridership are available so the final indicator will require a careful selection.

We suggest that the principle of measuring the same aspect from two contrasting perspectives (objective provision and users' perceptions, respectively) is transferred from TSB to monitoring of public transport integration. This means that we have to provide **subjective and objective indicators** which complement each other. To this aim, we propose that the whole structure of progress indicators is mirrored in one set of indicators that reflect objective data, and one set that represent users' perceptions on the same issues.

The data for the subjective measurements would require a survey, which should be designed to cover similar aspects as the objective indicators. It is also important that the computed indicator will be regarded as trustworthy and relevant by the user. To achieve this will require a careful consideration of the sampling frame, sample size, question formulation, etc. Initial suggestions for indicators and corresponding survey questions are given in Table 2.

Table 2. **A suggested indicator framework for measuring integration in public transport**

| *"Level"* | *Layer* | *Objective (indicators)* | *Subjective (survey)* |
|---|---|---|---|
| ***Outcome*** | **Use** | **Ridership** | |
| | | e.g. passenger-km | e.g. How often do you 'choose' to go by public transport (when you have other options available)? |
| ***Output*** | **Quality** | Accessibility | |
| | | e.g. Logsum | e.g. Do you think that public transport provides feasible travel options in your city? |
| ***Input*** | **System** | Connectivity | |
| | | e.g. as measured by Chowdhury et al (2014) | e.g. Do you perceive barriers when you transfer between lines and modes in the public transport system? |
| ***Input*** | **Process** | Cooperation | |
| | | e.g. collaboration across departments measured by Carreno et al. 2013 | e.g. Do you perceive the public transport system as being planned and operated by many different organisations or a single entity? |

# Discussion

The main aim of this work was to propose a potential monitoring tool for integration of public transport. Comparison between sustainable urban transport and public transport integration has shown that, despite the many similarities between these concepts, only a small part of a previously developed sustainability framework (TSB) is transferable. The structure of indicators for monitoring integration in public transport that we suggest in this paper is only a first step of development of a final tool. Nevertheless, we discuss the principal advantages and disadvantages of the framework in this section.

## Advantages of the suggested framework

Simplicity – The suggested framework introduces the layers of integration, connects them to impacts in the form of progress indicators and reflects the hierarchical structure of layers. The simple structure make possible to choose a visualisation which is demonstrative and easy to understand.

Terminology – The suggested progress indicators facilitate common understanding of what integration in public transport is and how aspects of integration connect to each other. We suggest terms (cooperation, connectivity, accessibility and ridership) that are already commonly intuitively understood and widely used. Therefore a wide range of literature is available with definitions and measuring processes which is a good starting point for selection of the final indicators.

Subjective and objective indicators of progress – a user's perception has a basic influence on how public transport is used. Therefore, the subjective indicators give decision makers user feedback on the perceived level of integration, and the perceived effects of applied measures. "Ridership" is the highest level (outcome) indicator of the tool to emphasise that there can be a difference between a well-integrated public transport system (supply side) and a well-used public transport system (considering also demand side constraints and needs).

## Challenges with the suggested framework

Lack of target group - In public transport integration, there are several stakeholders involved with very different interests. The effectiveness of a monitoring tool depends on the adequacy and relevance of provided results for the target policy-making group. Therefore, it is vital to have a clear picture of the intended target group for the monitoring results. This framework has no defined target group yet, therefore the final adaptation: adjustment of indicators, monitoring process and interpretation of results has not happened yet.

The "vision" problem – As in TSB, the measuring philosophy of the proposed framework is based on "how far we are from our own vision?" A future tool (based on this framework), will therefore not provide any feedback on how realistic the vision is in itself, or what level of integration that would be reasonable or optimal in the local area under study.

Limited monitoring scope - A focus specifically on the inputs within the field of integration, will inevitably mean that we ignore many other aspects that are important to increase quality and number of users of a public transport system

Standard vs. efficiency – The proposed framework does not yet include any indicators for the cost of providing a high level of integration (or high quality for users). This is a problem, since we would ideally want to reflect also how much resources we have used to achieve our vision.

## Recommendation for remaining work

Research indicates that a more integrated public transport system is desirable, and also that processes that are monitored runs more smoothly and attracts more resources and attention from decision makers. A monitoring system would enable decision makers to identify problem areas, locate weaker links in a process, measure and compare effects of applied measures, as well as report progress over a longer time period. Therefore, it may be worthwhile for public transport authorities to undertake the effort to develop a tool dedicated to monitoring of integration. For an effective development we suggest the next steps:

Identify a relevant target group that would use the indicators – Discussions with a dedicated target group will provide more details on the purpose of monitoring, which types of information that the tool should provide, the availability and requirements regarding data quality and data collection, and how much resources that could be expected for future monitoring and database maintenance.

Complete the framework with indicators - The complexity of the progress indicators requires a careful selection and relevant calculation of final indicators. Discussion with the target group will help to, for example, determine a relevant strategy for selecting indicators from the "long lists", define concrete calculation algorithms, weights, reference points and scale for indicators.

Decide on how results should be visualised – Following a decision to apply the proposed framework, selection and specification of sub-indicators, and piloting data collection procedures, the next step would be to discuss and develop a relevant format for visualisation that would allow qualified interpretation of results. Since integration is a complex process, it is vital to reduce the dimensionality of the results as much as possible, and show only the most relevant results in a very condensed format.

Monitoring plan – Finally, plans for recurrent production and evaluation of results, and also for data collection and data base maintenance, have to be decided. An important issue here will be the frequency with which results should be produced and communicated.

# References

Carreno, M., Vleugels, I., Backx, K., Clark, A., Neergaard, K., Evanth, K., Ivanova, E., Hudak, K., Kirkels, M. (2013) Ecomobility SHIFT – Assessment and Audit Scheme. Manual for Auditors and Advisors. ICLEI – Local Governments for Sustainability e.V. http://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/ecomobility_shift_shift_manual_for_auditors_and_advisors_en.pdf

Chisholm, D. (1989), *Coordination without hierarchy: Examining the dynamics of organizational behaviour*. An examination of organizational behavior within the context of San Francisco bay area transit organizations and the metropolitan transportation commission. University of California Press, Berkeley.

Chowdhury, S., Ceder, A., Velty, B (2014), "Measuring Public-Transport Network Connectivity Using Google Transit with Comparison across Cities", *Journal of Public Transportation*, Vol. 17, No. 4.

Dadson, J., Mees, P., StoneJ., Burke, M. (2011), "The principles of Public Transport Network Planning: A review of the emerging literature with select examples" Griffith University, Brisbane.

Goldman, J., Murray, G., Sullivan, C., Withaker W. (2014), *Improving transit integration among multiple providers Volume I: Transit Integration manual*, The National Academies Press, ISBN 978-0-309-30822-9

Hadas, Y., and P. Ranjitkar (2012)," Modeling public-transit connectivity with spatial quality-of-transfer measurements", *Journal of Transport Geography* 22: 137-147.

Handy, S., and D. A. Niemeier (1997), "Measuring Accessibility: An Exploration of Issues and Alternatives" in *Environment and Planning* A, 29, 1175–94

Kellerman, P., Degand, J-C. (2003), "A one-stop approach to Mobility: The challenge of integration" UITP, International Association of Public Transport.

Litman, T. (2016), "Well Measured: Developing Indicators for Sustainable and Livable Transport Planning", Victoria Transport Policy Institute, November 2016.

May, A.D., Kelly, C., Shepherd, S.P. (2006), "The principles of integration in urban transport strategies", *Transport policy*, No 13 (4) pp.319-327.

Mohring, H. (1972), "Optimization and Scale Economies in Urban Bus Transportation", *American Economic Review*, pp.591-604.

Murray, G., Sullivan, C., Goldman, J., Withaker, W. (2015), *Improving transit integration among multiple providers Volume II: Research Report*, The National Academies Press, ISBN 978-0-309-30823-6

Navarrete, F., and J. d. D. Ortuzar (2013), "Subjective valuation of the transit transfer experience: The case of Santiago de Chile", *Transport Policy*, No 25: pp.138-14.7

NEA Transport research and transport training (2003), *Integration and regulatory structures in public transport*, final report.

Niemeier, D.A. (1997), “Accessibility: An Evaluation Using Consumer Welfare.” *Transportation*. Vol. 24: 377-396

OECD (2003), *OECD Environmental Indicators: Development, Measurement and Use*. https://www.oecd.org/env/indicators-modelling-outlooks/24993546.pdf

Olofsson, Zs., Hiselius L., Várhelyi, A (2016), “Development of a tool to assess urban transport sustainability: The case of Swedish cities”, *International Journal of Sustainable Transportation*, Vol 10, Issue 7, pp.645-656, DOI:10.1080/15568318.2015.1055535.

Poorjafari, V., Poorjafari, M. (2011), “Integration in Urban Public Transport Systems” 13th international conference on Rail transportation.

Potter, S., Skinner, M. (2000), “On transportation integration: a contribution to better understanding”, *Futures*, No 32 (3-1) pp. 275-287.

PROSPECTS (2003), *European Union research project: Procedures for recommending optimal sustainable planning of European city transport systems*, Final Report, Leeds.

Solecka, K., Zak, J. (2014), “Integration of the urban public transportation system with the application of traffic simulation”, *Transportation Research* procedia No 3 (2014) pp.259-268.

SPUTNIC (2009), *Policy and Research Recommendations Report*, Final report, Brussels

Sustainable Measures (2010) http://www.sustainablemeasures.com/

Toth-Szabo, Zs., Várhelyi, A., Hiselius, L.,Koglin, T., Angjelevska, B., (2011), “Measuring sustainability of transport in the city – development of an indicator-set.” *Bulletin 261*. Traffic & Roads, Department of Technology and Society, Lund University, Lund.

Toth-Szabo, Zs., Várhelyi, A., Hiselius, L. (2012), “Mätinstrument för uppföljning av transporthållbarhet i svenska kommuner”. (Measuring instrument for monitoring sustainability of transport in Swedish municipalities, in Swedish). *Bulletin 270*. Lund University, Sweden.

UITP – Focus (2011), “Becoming a real mobility provider Combined mobility: public transport in synergy with other modes” *UITP position paper*.

UITP - Policy Brief (2016), “Public transport at the heart of the integrated urban mobility” UITP.

Yiu, K.A. (2005), “An integrated public transport system: a case study of Hong Kong” (thesis), University of Hong Kong.

# Notes

1 We chose the term subjective as a natural opposite to “objective”. However, the term is slightly misleading here: The “subjective perspective” does reflect typical perceptions and opinions held by the public. The corresponding indices are computed from objective measurements (survey data). Thus, they do not represent a “subjective” perspective of any specific individual.

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3 With that definition softer properties of the system such as the availability of web based travel planners, ticketing systems and fare structures, would in principle be included in connectivity. However those properties would probably be a bit more difficult to include in the computing method proposed by Chowdhury et al (2014).

International Transport Forum

**International Transport Forum**
2 rue André Pascal
F-75775 Paris Cedex 16
contact@itf-oecd.org
www.itf-oecd.org