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Sustainable mobility indicators for Indian cities: Selection methodology and application

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ABSTRACT

Various indicators of sustainable mobility have been developed. It is difficult to select the most relevant indicators that are useful in a specific context, and that are measurable and achievable at the same time. Indicator selection frameworks – criteria based; causal chains and causal networks have been proposed and used in the past. All three frameworks have certain limitations and strengths.

In this study we have proposed a systematic approach of selecting sustainable mobility indicators for Indian cities by combining – criteria based, causal chain and causal network frameworks. The methodology involves both subjective judgments for evaluation of indicators against a set of criteria and objectivity during development and assessment of causal network. The method results in identifying 20 relevant factors for which 32 indicators are shortlisted. Further work is required to develop measurable indicators related to accessibility to the disadvantaged, speed limit restriction and street lighting. These have not been discussed in detail in the existing literature. The 20 factors are classified as root nodes, central and end-of-the-chain nodes that helps in identifying levers of attaining sustainable mobility in Indian cities.

The developed causal network is evaluated for its ability to address all sectors associated with sustainable mobility. The causal network has low density and centralization index and therefore accounts for multiple factors. The shortlisted indicators are proposed for preparing low carbon mobility plan (LCMP) for three medium size Indian cities. The indicators are checked for data availability and ease of measurability based on the data collected for preparing the three LCMPs. The analysis shows that the data are available from secondary sources like census to measure root node indicators, whereas central indicators require conducting primary surveys and specific models are required to measure end-of-the-chain indicators.

Based on the position of indicators within causal network, it is interpreted that pricing policy, urban form and infrastructure are the levers of sustainable mobility. The indicators of energy consumption, emissions and accessibility are the sustainable mobility targets that we want to achieve.

1. Introduction

Indicators are widely used to evaluate progress, projects, and policies toward set goals and objectives. Organization for Economic Cooperation and Development Countries (OECD) define indicators as statistical measures of social, environmental and economic sustainability (Haghshenas and Vaziri, 2012). Indicators help in evaluating, simplifying, study trends, communicate issues and compare across places and situations (Boyko et al., 2012; DETR, 2000; Toth-Szabo and Várhelyi, 2012). A set of appropriate indicators allow decision makers to monitor status and understand consequences of the actions and inactions (Boyko et al., 2012; Gudmundsson and Sørensen, 2012; Henning et al., 2011; Rametsteiner et al., 2011). Even though a strong need of indicators to assess policy options is realized (Litman, 2007; Moussiopoulos et al., 2010; Zachariadis, 2005), their use in practice is missing (Gudmundsson and Sørensen, 2012).

The non-motorized transport (NMT) and public transport (PT) share is high in Indian cities (Wilbur Smith Associates, 2008) resulting in comparatively low per capita CO_2 emissions from transport sector (International Energy Agency, 2014). The existing infrastructure for NMT and PT is in poor condition or missing, NMT and PT users face high risk from traffic crash and discomfort. The majority of the NMT and PT users belong to low income groups who cannot afford other modes of transport and are therefore likely to shift to private motorized

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modes as and when they can afford it (Tiwari and Jain, 2013; Tiwari and Jain, 2008). To curb the increasing emission levels from urban transport it is required to retain the existing NMT and PT share in Indian cities (Jain and Tiwari, 2016). This requires sustainable mobility planning that ensures safe accessibility to all users of transport system irrespective of their socio-economic background (gender, income and caste) and mode used in a way that does not compromise with the health of the environment (UNEP, 2014). This definition draws focus on attaining social and environment sustainability. Planning for sustainable mobility requires assessing various aspects of transport using indicators as both cause and concern to identify issues, study trends and propose strategies.

Various institutes and authorities have developed sustainable mobility indicators for efficient planning. Even though consensus on meeting the 'triple bottom line' exists i.e. environmental, social and economic sustainability; yet different indicator sets have been used to evaluate transport systems (Miranda and Silva, 2012; Richardson, 2005). It is required to select limited indicators from existing long list that not only provides a holistic view of the system but also helps in meeting the planning targets (Castillo and Pitfield, 2010; Dale and Beyeler, 2001; Fusco, 2001). This requires answering several questions. How to decide what is the optimal number of indicators? What is the importance of each indicator in total indicator set? Do the selected indicators provide a complete picture of the system?

Transport is a complex system having many interacting sub-systems. Selection of indicator set should therefore take into account these interactions and consider feedbacks and rebound effects (Richardson, 2005). Accounting for dynamic interactions during indicator selection process can also help in avoiding double counting (Litman, 2009). Various indicator sets are used for mobility planning, however, the integrated approach of selection that considers these interactions is lacking (Huang and Lo, 2011; Moussiopoulos et al., 2010). Two more issues that require attention are – how to account for relationship between indicators and how to avoid double counting. In the study, indicator selection method is developed to address these issues.

Indicator selection frameworks can be classified as criteria based, causal chains and causal networks. The three frameworks have certain limitations and strengths. In this study, we have explored the potential of each of the three frameworks and developed a methodology by combining them to select indicators of sustainable mobility in Indian cities. Later, the shortlisted indicators are evaluated based on the robustness of causal network and data availability and measurability.

2. Indicator selection frameworks

2.1. Criteria based framework

In this approach, indicators are rated against selected criteria deemed important by expert group and stakeholders. Using appropriate aggregation methodology indicators are ranked and selected.

Some of the key criteria used for selecting indicators are data availability; measurability; utility; sensitivity; transparency and interpretability (Table 1). The majority of the studies emphasize importance of data availability to measure indicators using scientifically sound and acceptable method (Bojkovic et al., 2010; Castillo and Pitfield, 2010; Dale and Beyeler, 2001; Gilbert et al., 2002; Gilbert and Tanguay, 2000; Haghshenas and Vaziri, 2012; Henning et al., 2011; Joumard et al., 2011; Lin et al., 2009; Moussiopoulos et al., 2010; Nicolas et al., 2003). Application of this criterion ensures reliability of the information delivered and allows regional and temporal comparison. In the project Sustainable Transport Performance Indicators (STPI) – Phase III, indicators for which data was available from federal government sources were selected (Gilbert et al., 2002; Gilbert and Tanguay, 2000).

Castillo and Pitfield (2010) discuss speed of data availability as an important criterion for selection of indicators. This shall enable short time lag between changes in the phenomenon under study and the availability of measured indicators. In STPI-phase III Project, the indicators were selected that could also be studied over time (Gilbert et al., 2002; Gilbert and Tanguay, 2000). Castillo and Pitfield (2010) and Moussiopoulos et al. (2010) also mention the need for being able to forecast indicators. This helps in studying trends and estimate progress toward the set goals under identified scenarios.

Litman (2009), Bojkovic et al. (2010) and Toth-Szabo and Várhelyi (2012) discuss the need to avoid conflicting indicators in the final set. For example, increase in mobility and reducing emissions are two conflicting targets (Toth-Szabo and Várhelyi, 2012). The selected indicators should provide unambiguous, specific information that can be used for decision making to achieve the set goals. They should be clear and easily understood by its intended users (Bojkovic et al., 2010; Castillo and Pitfield, 2010; Dale and Beyeler, 2001; Haghshenas and Vaziri, 2012; Joumard and Gudmundsson, 2010; Litman, 2009; Moussiopoulos et al., 2010; World Bank, UNEP, UNDP, and FAO, 1998).

Studies also emphasize the role of policy or target relevant indicators (Castillo and Pitfield, 2010; Dizdaroglu, 2015; Gilbert et al., 2002; Haghshenas and Vaziri, 2012; Henning et al., 2011; Joumard et al., 2011; Lin et al., 2009; Moussiopoulos et al., 2010; Toth-Szabo and Várhelyi, 2012). Indicators that are not policy relevant may provide wrong interpretations and result in misguiding decision makers. Castillo and Pitfield (2010) highlight the need of using indicators for which transport impacts can be isolated. Gilbert et al. (2002) give an example of selecting indicator of emission from transport sector as opposed to using air quality index. The former provides information on the impacts of transport sector while in later the influence of transport sector is unknown. The study by Lin et al. (2009) and joint report by World Bank, UNEP, UNDP, and FAO (1998) specify the need for selecting indicators that can be controlled by management and policy actions.

There is a growing body of research, which identifies the need of context specific indicators. Such indicators provide understanding of local community needs and reflect changes in urban structure and transport sector of cities (Boyko et al., 2012; Haghshenas and Vaziri, 2012; Joumard et al., 2011; Toth-Szabo and Várhelyi, 2012). As per Toth-Szabo and Várhelyi (2012) indicators should reflect the value systems of people. The authors therefore have not included poverty related indicators of mobility for Sweden in their final set. Moussiopoulos et al. (2010) included indicators related to sea environment and tourism to measure urban sustainability in Thessaloniki, Greece.

Another important criterion identified in literature is comprehensiveness. This criterion is used to evaluate ability of indicator set to measure different dimensions associated with the system under study (Bojkovic et al., 2010; Dale and Beyeler, 2001; Gilbert et al., 2002; Lin et al., 2009; Litman, 2009; Nicolas et al., 2003).

Table 1 presents the summary of criteria used for selecting sustainability indicators arranged in chronological order. As the table shows, earlier studies have used criteria related to data availability, measurability and interpretability for selecting indicators. However, recent studies emphasize the need for context specific interventions.

Haghshenas and Vaziri (2012), Toth-Szabo and Várhelyi (2012) and Wang et al. (2009) highlight the need for uncorrelated indicators to avoid double counting. The duplicity in information revealed through the indicators results in giving over-emphasis on few issues instead of providing a comprehensive understanding of the system. In contrast to this, Rowley et al. (2012) argue that it is difficult to select a set of mutually independent indicators. The study provides an argument for the need to consider cause-effect chain relationships during indicator selection.

2.2. Causal chain frameworks

Causal chain frameworks account for linear relations between indicators of interest. Pressure, State and Response (PSR) framework