Transport impact indicators for monitoring the sustainability of urban growth: Findings from a Delphi study

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Abstract

The selection of a right transport impact indicator of urban growth is challenging because the impacts vary both geographically and temporally. This research contributes to addressing this challenge. First, the study systematically selects 23 indicators from a pool of 62 indicators initially identified from the literature. Second, it evaluates and classifies their suitability into four groups (suitable at a particular spatial scale, a particular temporal scale, multiple spatial scales, and multiple temporal scales) through a two-round of Delphi survey involving 29 experts drawn from related sectors and from across the world. In Round 1, experts were requested to indicate the suitability of the indicators for a particular spatial/temporal scale on a 5-point Likert scale. Four summary statistics were derived using the responses to assess the consensus level among the experts: median, expected probability of occurrence, interquartile range, and standard deviation. In Round 2, experts were requested to indicate the extent they agree with the achieved consensus level and an increment of agreement between the two rounds was calculated. Results show that experts reached a consensus on 12 (52%) indicators. ‘Travel time’ was identified as a suitable indicator for all three spatial (local, city, region) and two temporal (short and long) scales. The remaining 11 indicators are suitable for only specific spatio-temporal scales. The findings serve as a guide for decision-makers, transport modelers and planners to adopt indicators according to their scale of operation.

1. Introduction

Several studies have indicated that urban areas are growing unsustainably (Mavrakis et al., 2015, Reilly et al., 2009, Jabareen, 2006). The sustainability assessment of urban growth is often centred on specific sectors in these studies (e.g. transport, water, agriculture) (Mavrakis et al., 2015, Shiftan et al., 2003, Wheeler et al., 2013, Pahl-Wostl, 2002). They have employed a range of indicators to assess the sustainability of urban growth. However, the selection of indicators is often based on an ad-hoc method (AtKisson, 1996). The problem with this approach is that the selected indicators might not be transferable to different spatial and temporal scales. This research aims to employ a systematic method to select the right indicators for specific spatial and temporal scales for the assessment of transport impacts of urban growth.

The selection of right indicators for assessing the transport impacts of urban growth is challenging for two reasons. First, the impacts can be very different from one geographic scale to another. Second, the impacts can vary at different temporal scales. These challenges often required selection of different indicators for different spatial and temporal scales (Dobranskyte-Niskota et al., 2007), and as a result, existing transport impact assessment studies explicitly delimit spatial and temporal scales (Perveen et al., 2016). The

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problem with these separate transport impact assessment exercises is that the outcomes are not communicable across spatial and temporal scales for a comprehensive and consistent decision-making.

This research intends to contribute to resolving the challenges by systematically identifying the suitability of various indicators to be used to assess the transport impacts of urban growth stratified by: a) spatial scale specific; b) temporal scale specific; c) spatial scale variant; d) temporal scale variant; and e) space and time variant. Initially, the research identifies all indicators used to assess transport impacts based on the literature. These indicators can broadly be categorised into four sectoral groups: a) transport (mode choice); b) land use (land required to facilitate transport infrastructure for growth areas); c) environment (additional CO_2 emissions from transport sector for urban growth); d) economic (extra jobs in transport sector). The spatio-temporal suitability of these indicators was assessed through a two-round of Delphi survey process as outlined in MacCarthy and Atthirawong (2003), involving 29 experts drawn from related sectors and from across the world.

2. Methodology

2.1. Development and pre-testing of a Delphi survey questionnaire

A total of 62 transport indicators were initially identified from the literature. These indicators were then screened for their relevance to urban growth, and 23 indicators were selected (Table 1). An online based Delphi survey questionnaire was designed using the Key Survey tool. The questionnaire contained a question for each of the selected 23 indicators grouped into four categories for organisational purposes as outlined in Table 1 but they all reflect transport impacts of urban growth. The questionnaire was designed in a way so that the experts can rate the importance of the indicators six times based on a 5-point Likert scale (1 – very low to 5 – very high): one rating for each of the three spatial scales (local, city and regional), and three temporal scales (short-, medium- and long-term). In addition, options were kept for the experts to suggest any indicators that they thought relevant for this research. The designed questionnaire was sent to 3 local experts initially in order to check for clarity and consistency; subsequent changes were made to the questionnaire based on their comments and suggestions. Necessary ethical clearance was obtained prior to conducting the Delphi survey.

Table 1: Suggested indicators for assessing transport impacts of urban growth scenarios

Transport	Land use	Environment	Economy
Mode of transport (public, private)	Land take by transport infrastructure	Energy consumption	Investments in transport infrastructure
Travel cost	Transport network density	Greenhouse gas emissions	Growth in transportation network relative to growth in the economy
Travel distance	Access to public transport services	Noise pollution	Transportation productivity (labor productivity or total-factor productivity)
Travel time	Land use change (new development)	Traffic accident incidence	Subsidies in transport sector
Trip purpose	Location of employment centres		Employment in the transport sector
Private car ownership	Housing demand		
Freight transport trends by mode	Location of commercial activity zones		

2.2. Identification of experts and Delphi survey

This research used three criteria to select the experts: a) relevant experience and expertise measured in terms of their years of experience; b) geographical diversity for the external validity of the selected indicators; c) sectoral diversity given that the indicators cover a wide range of sectors. A list of 100 experts was prepared by reviewing their online profiles. Particular emphasis was placed to select experts/practitioners and academicians from the priority disciplines viz. urban planning, transportation, economic development, environment, and social planning. The Delphi survey was conducted in two rounds. In Round 1, the importance and validity of the selected 23 indicators were assessed in terms of consensus level among the experts. An invitation was sent to the identified 100 experts with a link to the survey questionnaire in during October to December 2016. Out of 100 experts invited, 35 agreed to participate, and 29 completed the survey successfully, yielding a response rate of 29%. The sample size was found to be representative of previous studies using Delphi survey for instance Cavalli-Sforza and Ortolano (1984) used 17; Wang et al. (2014) used 99; and Kiba-Janiak (2016) used 20 in transportation studies.

The ratings provided by the experts in Round 1 were analyzed to identify the indicators that already reached a consensus and the indicators that did not. Four summary statistics were derived using the responses to assess the consensus level among the experts: median, expected probability of occurrence, interquartile range, and standard deviation. These statistics were provided with each indicator for all spatial and temporal scale in Round 2 of the survey. A 50% cut-off point was set for the consensus level based on the literature (Schuckmann et al., 2012). Experts were asked to provide their opinion on the statistical summary provided by asking the following question: 'to what extent do you agree or disagree with the scores' based on a 5-point Likert scale (1 – Strongly Disagree to 5 – Strongly Agree). The survey was executed during February to March 2017.

2.4 Analysis of Delphi survey responses

Round 1: Median score was calculated to measure the central tendency and the level of dispersion was derived through standard deviation (SD) and interquartile range (IQR) in order to analyze the collective judgments of respondents for each indicator (Keeney et al., 2010, Schuckmann et al., 2012). The median score and expected probability of occurrence (EP) were used to provide feedback on the level of consensus of Round 1 to the experts in Round 2. The expected probability of occurrence (EP) was calculated to represent the frequency of responses on a scale of 0-100% i.e. if 60% of experts rated an indicator as "Highly important" the calculated EP is 60% (Corbin and Strauss, 1990). An EP of at least 50% on a scale 0–100% is used as a standard measure for consensus level (Schuckmann et al., 2012, Heiko, 2012).

Round 2: Although the responses were collected on a 5-point Likert scale in Round 2, these were recorded on a 3-point scale in order to create more meaningful categories based on the literature (Linacre, 2002, Andrich, 1978). The 'agree' and 'strongly agree' categories were combined to obtain the percentage of agreement whereas the 'disagree' and 'strongly disagree' categories were combined to obtain the percentage of disagreement. The category "neutral" was retained as "neutral". The increment of agreement between the two rounds of the survey was used to assess the consensus level of the ratings on indicators. The increment of agreement was calculated based on differences in agreement (%) of an indicator between Round 1 and Round 2 (Holey et al., 2007).

3. Results

In the first round of Delphi survey, consensus was achieved for 30 indicator-scales out of 138. Among these, 12 gained consensus in the spatial scales, and the remaining 18 indicator-scales gained consensus in the temporal dimension. These 30 indicator-scales involved 15 indicators (reached consensus on any spatial and temporal scale). Out of 12 indicators reached consensus on spatial scale, only 2 indicators were for local, 6 for city and 4 indicators for regional scale. Furthermore, out of 18 indicators gained consensus for spatial scale, there were 6 for short-term, 9 for mid-term and 3 for long-term scale. However, none of these indicators reached a consensus for all spatial and temporal scales in this round. Three indicators reach a consensus of maximum 4 scales out of the 6 scales and include: investments in transport infrastructure, location of employment centres and travel time. Even none of the indicators was found to reach a consensus for all spatial scales or for all temporal scales.

The sector wise distribution of indicators with their consensus levels shows mixed results. In total 11 indicators from transport, 9 indicators from land use, 2 indicators from environment and 8 indicators from economic sectors gained consensus out of total 138 indicator-scales. Therefore, in transportation sector, only 26% consensus achieved out of 42 indicator-scales in transport sector (i.e. 7 indicators with 6 scales). In land use sector the consensus level was 21% out of 42 indicator-scales (i.e. 7 indicators with 6 scales). On the other hand only 8% of consensus level achieved out of 24 indicator-scales in environment sector (i.e. 4 indicators with 6 scales). Similar to the transport sector, the economic sector achieved 26% consensus level out of 30 Indicator-scales (i.e. 5 indicators with 6 scales). In view of above discussion, the results reveal important but not enough significant outcomes in the remaining 108 indicators which suggested a weak agreement among experts on the importance of ratings for these indicators. Based on the results from Round 1, the questionnaire in Round 2 contained the remaining 108 indicator-scales for further assessment by the experts. The experts in Round 1 of the survey did not suggest including any new indicators for further consideration.

In Round 2, only 14 indicator-scales gained consensus out of 108. The indicators that gained consensus in Round 2 are: mode of transport, travel distance, travel time, land take by transport infrastructure, transport network density, access to public transport services, land use change (new development), Location of commercial activity zones, energy consumption, greenhouse gas emissions and growth in transportation network relative to growth in the economy. There was a strong agreement of increment for these indicators in the second round of the survey. However, when the 50% increase in agreement between the two rounds was used as consensus criterion, the results show that only 14 (12.9%) indicator-scales reached a consensus in the second round. Overall, 12 (52%) out of the 23 indicators gained consensus on at least one spatio-temporal dyad as shown in Table 2. Furthermore, the importance rating of these indicators was also specified by the experts. Out of 37 indicator-scales, only 11 indicators have gained consensus as medium important while remaining 26 indicators have gained consensus as highly important for assessing transport impacts of urban growth in their relevant spatial and temporal scale.

Table 2: Key Transport indicators according to their Importance level in spatial and temporal scales

	Spatial			Temporal			
Indicators	Local	City	Region	Long-term	Mid-term	Short-term	Total
Mode of transport (public, private)		High			High		2
Travel distance	Medium		High	High		Medium	4

Indicators	Spatial Local	 City	 Region	Temporal Long-term	 Mid-term	 Short-term	Total
Travel time	High	High	High	High		Medium	5
Transport network density		High			High		2
Access to public transport services	High	High		High	High		4
Land use change (new development)		High	Medium				2
Location of employment centers		High	High	High	High		4
Housing demand		High			Medium	Medium	3
Location of commercial activity zones	High	High					2
Greenhouse gas emissions		High			High		2
Investments in transport infrastructure	Medium	High			High	Medium	4
Transportation productivity (labor productivity or total factor productivity		Medium			Medium	Medium	3
Total	**5**	**11**	**4**	**4**	**8**	**5**	**37**

5. Conclusion and discussion

This study is an effort towards monitoring the urban growth scenarios through assessing the transport impacts by selection of representative indicators at different spatial (region, city, local) and different temporal (long-, medium-, short-term) scales. The presentation of space-time dyad of indicators in this research ease the indicator selection process by answering questions like: which indicators are suitable for a regional scale to monitor transport impacts of urban growth over a long-term period? Or which indicator is suitable for all spatial and temporal scale to assess the transport impacts of urban growth? The identified list of indicators appears sufficiently well defined on different spatial and temporal scales may help to form the basis for a further research to assess the transport impacts for achieving sustainable urban growth policies. The most important indicator identified by the expert panel was the travel time because of its suitability for all spatial and two temporal scales. In contrast, some indicators were found to be suitable for specific spatial and temporal scales. For example, mode of transport is a suitable transport indicator if applied in city level to assess mid-term impact of urban growth.

The results are supported by the findings as reported in the literature (Santos and Ribeiro, 2015, Castillo and Pitfield, 2010, Bajdor and Grabara, 2013, Haghshenas and Vaziri, 2012, Hiremath et al., 2013). Some of the indicators might be correlated to each other, and therefore, it is important to assess their association before operationalising in a case study setting.. Final indicator list is a generic one that requires ground-truthing and customisation before implementation in a local context. Our prospective research will focus on these limitations.

6. References

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