Capturing Sustainability Goals in City Logistics: A Delphi Approach to Develop Sustainability Indicators

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1. INTRODUCTION

Sustainable development in city logistics has been addressed frequently and prominently by the government, local authorities and the logistics industry. There is a need for city managers and city logistics service providers to understand each other's sustainability agendas and priorities. A set of commonly agreed indicators for performance measurement would be beneficial for both parties to collaboratively conduct sustainability reporting and assessment. However, developing useful indicators for measuring sustainability in city logistics is challenging as there are many uncertainties and multiple stakeholders' interests to consider. A lack of a systematic decision-making process to engage public and private stakeholders to design the sustainability indicators often results in poor applicability and data availability.

This study uses a Delphi survey method to firstly capture how public and private stakeholders in city logistics define sustainable city logistics and perceive sustainable goals, and then evaluate relevant indicators for measuring these sustainable goals in city logistics.

This aim was achieved by addressing two research questions (RQ):

RQ1: What are major stakeholders' perceptions of sustainable goals for city logistics?

RQ2: What are the relevant indicators to measure sustainability in city logistics?

2. LITERATURE REVIEW AND THEORETICAL CONSIDERATIONS

2.1 The complexity of the city logistics ecosystem

City logistics is a complex ecosystem that involves many logistics activities, actors and stakeholders. Maxner *et al.* (2022, p.1) describe this disaggregated and unorganised system as 'a system that is not organised at the municipal scale and that is driven by performance and customer expectations'. Sustainable city logistics is a concept with many subjective interpretations by different actors in the ecosystem of urban freight transport (Behrends *et al*., 2008). Given the heterogeneity of the various stakeholders in city logistics (Anand *et al.*, 2012), the public and private stakeholders do not necessarily have the same perceptions, objectives, or visions for 'sustainable city logistics'.

2.2 Relevant frameworks for sustainability assessment

Sustainability assessment tools can be categorised into three main types, namely: indicators and indices, product-related assessment tools and integrated assessment (Ness *et al*., 2007). Indicators/indices and integrated assessment have a wider spatial coverage and both are used to support policy development and project implementation; whereas product-related assessment tools tend to focus on produce level assessment using life cycle analysis methods (Ness *et al.*, 2007). Many global sustainability frameworks have been identified related to the logistics field (see Table 1).

Table 1 Overview of sustainability frameworks applied in the logistics industry

Framework	Year Established	Scope	Assessment Method	Data Collection Method
U.N. SDGs	2015	Global; Country level	Non-integrated indicators	Contact with national entities
GRI Standards	1997	Global; Firm level	Non-integrated indicators	Company-lead reporting based on guidelines
SmartWay	2004	US & Canada; Firm level	Integrated impact assessment	Emissions data from freight transport companies
GLEC Framework	2016	Global; Europe Firm level	Integrated impact assessment	Emissions data from freight transport companies
CDP	2002	Country; City; Firm	Index based on the scoring method	Questionnaire
Sustainability Accounting Standards Board (SASB) Standards	2011	Sector; Firm	Non-integrated indicators	Questionnaire
Dow Jones Sustainability Index (DJSI)	1999	Country; Regional	Integrated index	Questionnaire; documentation; media; contact with companies.

Source: Author's own

2.3 Measuring sustainability in city logistics ecosystem: Initial theoretical framework

Sustainability is highly salient in the city logistics research studies while studies on 'sustainability measurement' are deficient.

This study proposes the '*Define-Design-Develop-Deploy'* (named in this study as '4D stage model') stage model for sustainability indicator development. Relevant research studies in city logistics context were mapped out using this 4D stage model (see Table 2). Each stage is defined as below:

1) 'Define' Sustainability Measurement Goals: Propose sustainable goals for city logistics and frame the scope for measurement.
2) 'Design' Indicators Frameworks: Identify indicators and develop a typology for categorising indicators.
3) 'Develop' Sustainability Measurement Indicators: Select or test the proposed indicator's applicability for sustainability measurement.
4) 'Deploy' Indicators: Implement the indicator framework to assess the sustainability performance and impact in the city logistics ecosystem.

Table 2 Sustainable indicator design process in urban freight transport related literature

Design Process:	Stage I *'Define' Goals*	Stage II *'Design' Indicators Frameworks*	Stage III *'Develop' Indicators*	Stage IV *'Deploy' Indicators*
Behrends *et al.* (2008)	Proposed	Proposed based on Literature	N/A	N/A
Morana and Gonzalez-Feliu (2015)	N/A	Literature	Develop with 25 logistics managers	N/A
Kiba-Janiak (2015)	N/A	Literature; EU statistics, reports and projects, and national statistics	N/A	Test using the Electre III/IV method based on secondary data
Cheba and Saniuk (2016)	N/A	Literature	N/A	Test using the vector calculus method based on secondary data
Österle *et al.*(2015)	N/A	Literature	A single case study with multi-stakeholders	N/A
Buldeo Rai *et al.* (2018)	N/A	Literature	N/A	Test using a single case study with multi-stakeholders

Source: Author's own

3. METHODOLOGY

A qualitative approach by using the Delphi survey method was chosen in this study for two reasons.

First, based on the overarching sustainability indicator development principle (Hardi and Zdan, 1997; Meadows, 1998; Behrends *et al*.,2008), it is crucial to understand the different objectives from different stakeholders in the city logistics before proposing indicators for sustainability measurement. The Delphi approach enables researchers to solicit experts' opinions through an anonymous and geographically dispersed expert panel.

Second, when a large number of provisional indicators are involved, the Delphi survey is better suited to avoid a relatively long questionnaire design compared to other multi-criteria evaluation methods such as AHP or ANP (Ahmad and Wong, 2019). The two-rounds of moderated survey process also ensure the flexibility to capture both qualitative (open questions) and quantitative data (scale rating questions).

A heterogeneous Delphi expert panel consisting of academic experts, local authorities, and logistics service providers was formed with 50 city logistics experts in Europe. The panel experts were selected following the 'Knowledge Resource Nomination Worksheet' guideline by Okoli and Pawlowski (2004). The geographic scope of participants in this study was set in Europe, with an aim to obtain knowledge and experiences from experts in different European countries, particularly, those who were engaged in the high-level European Union-funded city logistics-related research projects.

Table 3 Delphi panel formation in this study

Stakeholder Group	Number	Country	EU-level City Logistics Projects that Experts Involved in
Government Experts	9 (18%)	Ireland (3) Norway (1), Sweden (1) Belgium (1), France (1) The Netherlands (1), Germany (1)	CIVITAS ECCENTRIC MOVE21 RESOLVE SENATOR
Industry Experts	14 (29%)	Ireland (7) UK (2), France (1), Czech Republic (1), Germany (1) Sweden (1), USA (1)	N/A
Academic Experts	27 (54%)	Belgium (4), The Netherlands (5) Ireland (3), Greece (3) Czech Republic (2), France (2) Poland (2), Sweden (2) Germany (1), Italy (2), UK(1)	CityChangerCargoBike CIVITAS ECCENTRIC CIVITAS PORTIS CITYLAB NOVELOG RESOLVE SENATOR SUGAR
Total	**50 experts**	**From 22 cities; 14 countries**	**9 Projects**

In line with the '4D' indicator design stage model discussed earlier, a two-round Delphi survey questionnaire design was used in this study. The Delphi survey process in this study is illustrated in Figure 1 below.

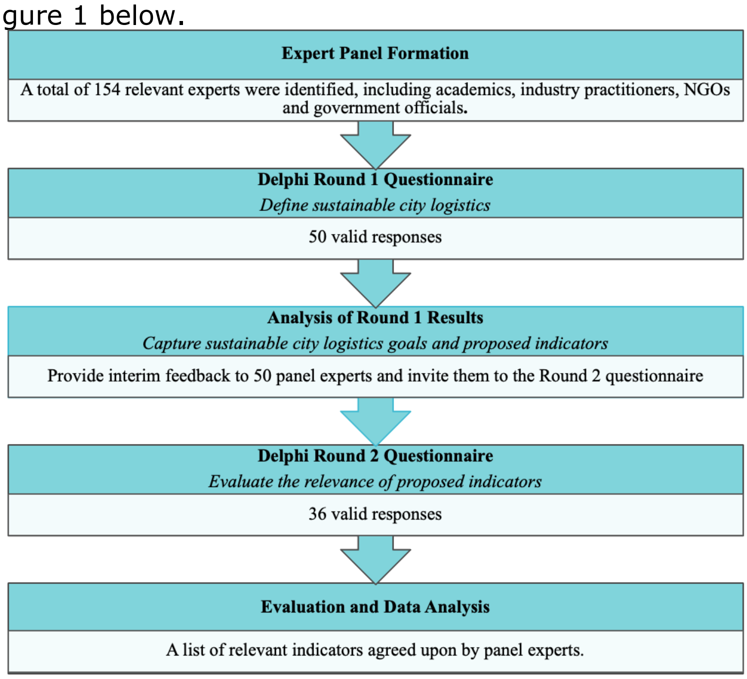

Figure 1 The Delphi survey process

A niche form of the "Policy Delphi" technique was incorporated in the data analysis to capture diverse views from the heterogenous panel (De Loë, 1995). Thus, to maximise the full potential of the Delphi study, the Delphi design in this study does not only measure the consensus on sustainability issues in city logistics, but also captures the diverse ideas among experts.

4. FINDING AND DISCUSSION IN BRIEF

The overall aim of the two-round Delphi survey analysis is to elicit the perception of sustainable city logistics among the panel experts, capture the sustainability goals among public and private stakeholders, as well as to identify the most relevant sustainability indicators for measuring against these goals in city logistics. The analysis in this section is structured around the two research questions (RQs). For each RQ, relevant empirical data are presented.

4.1 Sustainable city logistics goals perceived by stakeholders

RQ1: What are major stakeholders' perceptions of sustainable goals for city logistics?

The Delphi Round 1 questionnaire adopted an exploratory approach with open questions to ask panel experts' opinions on the issue of 'sustainable city logistics'. 45 out of 50 experts answered the open question '*what is sustainable city logistics*?'. The definition of 'sustainable city logistics' and different sustainability goals proposed by the public and private stakeholders were captured using thematic analysis.

'Sustainable city logistics' is difficult to define in concise words, and it is as multifaceted as perceived by different stakeholders in the city logistics ecosystem. Behrends et al.'s (2008) study entitled *'The Impact of Urban Freight Transport: A Definition of Sustainability from an Actor's Perspective'* is one of the pioneering research studies to provide a comprehensive definition of sustainability in city logistics, especially from a multi-stakeholder perspective. Based on Behrends *et al.*'s (2008) foundation, some new goals for sustainable city logistics have been identified and assessed by panel experts (see Figure 2).

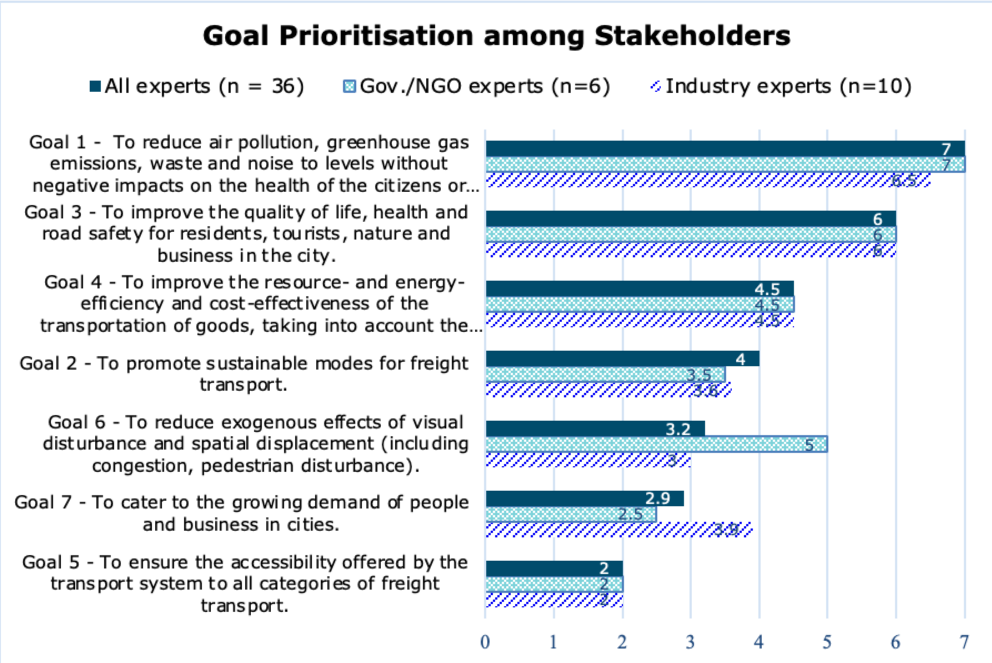

Figure 2 Ranking of sustainable city logistics goals by 36 panel experts in Round 2 Delphi survey

4.2 Sustainable city logistics indicators

RQ2: What are the relevant indicators to measure sustainability in city logistics?

In the Delphi Round 2 questionnaire, a list of 42 provisional indicators which were developed based on literature (indicator list as in Zhang *et al*., 2019), sustainability reports and experts' nominations were assessed by Delphi panel experts in terms of their relevance in capturing the sustainability goals in city logistics. The indicators' relevance rating and group consensus were analysed following the guideline of De Loë (1995). A total of 21 most relevant indicators were identified (see Table 5).

Table 4 Indicators for Measuring the Sustainability of City Logistics

	Environmental Indicators	Social Indicators	Economic Indicators
Most relevant indicators (n = 21) (Relevance rating median ≥4; group consensus > 70%)	• Low emission/ clean air zone (Relates to policy, urban air pollution, vehicles regulation, and city access restrictions) • Tailpipe carbon dioxide equivalent (CO2e) emissions per tonne-km per mode of freight fleet (kg/tkm) • Alternative fuel technology availability and infrastructure * • Logistics land use planning/ urban sprawl • Noise exposure level by freight vehicles and operations to individuals • Fleet compositions in the city centre and the greater urban areas (%) • Travel times in peak hours relative to travel times during non-congested periods (%) • Share of vehicles complying with Euro V or VI standards (%) • Delay in goods delivery due to congestion (hours) * • Lane occupancy/ parking space occupation by freight vehicles * • Fixed linkage to the implementation of Sustainable Urban Mobility Plans (SUMPs) * • Carbon tax *	• Number of road accidents caused by freight vehicles (Reflects road safety exposure to individuals and other road users)	• Road freight vehicle load factors (during the laden trips) • Change in share of vehicle-km made by low/ zero emission delivery methods * • Freight vehicle-kilometres (vkm) (total, peak and off-peak) * • On-time deliveries rate (represents shipments delivered by their estimated delivery date as a percentage of total tracked shipments) • Distribution distance travelled by delivery vehicles (on large roads, small residential roads) • Ratio of freight vehicle delivery time spent driving/parking at delivery stops/ unloading/loading time/other idling time * • Logistic movements per inhabitant (Related to personal shopping trip) * • Transport investments in sustainable development *
Relevant but less common indicators (n = 10) (Median ≥ 4; 50%<consensus < 70%)	• Transport spatial footprint (m²) (represents the surface allocated to transports in the city) * • Air quality Index * • Share of the length (km) of environmentally friendly transport (road, rail, etc.) per city area (%) • Number of loading/unloading zones per city area • Number of active council & government sustainability initiatives dedicated to freight transport in cities • Number of sorting centres, distribution centres and depots • Congestion charge	• Citizen satisfaction with public transport (%) Reflects the accessibility to urban public transport in the city • Citizen satisfaction to live in the city (%)	• Customer satisfaction metrics on freight delivery services (i.e. NPS)
The least common factors (n = 11) (Median < 4; consensus < 50%)	• Number of local collect locations (i.e. parcel lockers, parcel shops) • Citizen satisfaction with the noise level (%) • Number of sustainable businesses with certification ISO 14001 international standard for environmental management systems • Citizen satisfaction with the quality of the air (%) • Traffic control after midnight *	• Citizen satisfaction with the state of the street and buildings (%) (Relates to streetscape and urban road planning) • Community segregation caused by transport arteries *	• Homes served per day • Number of employments created in urban transport sector • Consumer footfall * • Commercial input/consumer input into sustainability initiatives *

Note: Indicators marked with * are proposed by the panel experts in this study.

5. CONCLUSION AND FUTURE RESEARCH DIRECTIONS

5.1 Summary of key contributions

Some key contributions of this working paper can be concluded as follows:

- By engaging with experts from 22 different cities as a novel data corpus, this study extends the empirical observations to investigate the perception on sustainability goals for city logistics, and subsequently assess the relevance of indicators for measuring against such goals;
- Radical and innovative ideas identified among experts during the process help to gain a richer and more balanced picture of sustainable city logistics from a multi-stakeholder perspective;
- The findings advance the understanding of sustainable city logistics in the current era;
- The proposed '*Define-Design-Develop-Deploy*' indicator development stage model in line with the design thinking for sustainability development has brought new disciplinary perspective into the logistics research.

5.2 Limitations and future research

This study did not include citizens and consumers, future research could engage wider public stakeholder groups to validate the proposed goals and indicators for city logistics.

This study did not conduct the 'deploy' stage, that is to implement the indicators. Thus, data availability and the robustness of the proposed indicators should be further investigated.

REFERENCES

(Due to page limit, a full reference list is provided upon request.)