CHAPTER 10

Facilitating Sustainable Logistics Policy Development Using Multicriteria Satisfaction Analysis: A Case of Preference Mapping for Cargo Bike Last-Mile Delivery

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Abstract We recommend facilitating sustainable logistics policy development using multicriteria satisfaction analysis. With regard to this policy recommendation, through a case study of preference mapping for cargo bike last-mile delivery we demonstrate the following: (1) The proposed

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MUlticriteria Satisfaction Analysis (MUSA) based public perception elicitation survey tool offers an alternative approach to map public preferences in sustainable policy decision-making; (2) The findings suggests different cities have different sustainability priorities for sustainable urban freight transport; and (3) City managers and logistics practitioners could offer tailored policies and services to address citizens' needs.

Keywords Public opinions · Urban logistics · Cargo bikes

Introduction

Public Participation in Urban Logistics Policy Development

The booming of e-commerce and on-demand instant freight deliveries in the city bring changes in economic activities, consumption behaviours, demand patterns, and disruptions in mobility, which posed substantial challenges to urban logistics operations (Dablanc, 2023; Dablanc et al., 2017). The urban shipments become smaller and fragmented, resulting in an increased number of direct delivery trips to home destinations (Amling & Daugherty, 2020; Dablanc, 2019; Hopkins & McCarthy, 2016).

Urban logistics has a significant impact on the functionality of urban areas and the well-being of their citizens. In fact, 70% of the European population lives in cities and 23% of EU transport greenhouse gas emissions come from urban areas (European Commission, 2024). The European Green Deal has set its target to achieve a 90% reduction in

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transport-related greenhouse gas emissions by 2050, compared to 1990 levels (Tsavachidis & Le Petit, 2022). Along with the New European Urban Mobility Framework launched in 2021, the European Commission has put urban mobility and logistics in the spotlight of the policy agenda.

In urban mobility and logistics policy development, stakeholder engagement is a crucial component of Sustainable Urban Mobility Plans (SUMP) and Sustainable Urban Logistics Plans (SULP), as well as in the New EU Urban Mobility Framework. Public engagement in policymaking ensures an inclusive and effective planning process; it involves a range of activities, such as public consultation, dialogue, and participation. To develop urban logistics policies, researchers in the urban logistics field have tested various forms of public engagement with citizens, such as focus groups (Tuomala et al., 2023) and living labs (Maltese et al., 2023). Yet, public participation is still a challenging task due to limited resources and policy tools (Maltese et al., 2023), and insufficient information provided to the public to make informed choices (Tuomala et al., 2023).

Cities vary in their approaches to visioning and planning sustainable mobility, so is their key stakeholders' opinions (Foltýnová et al., 2020). The stakeholders' perception and endorsement of the sustainable mobility concept and their ability to express their views will impact on urban mobility decisions (Foltýnová et al., 2020). Therefore, there is an urgency for decision-makers to capture public's opinion and investigate citizen's preferences on last-mile delivery solutions, thus, to provide tailored policies in the local context.

To address this challenge, the Social Sciences and Humanities (SSH) research agenda emphasises the importance of interdisciplinary research to address critical societal challenges in sustainable transport and mobility development (Ryghaug et al., 2023). Researchers advocate for more inclusive and deliberative approaches in collaboration with actors and stakeholders to enhance the effectiveness of policymaking (Ryghaug et al., 2023). In response to this "SSH CENTRE" project's vision to encourage SSH-STEM collaboration, our research contributes novel perspectives from the fields of logistics and supply chain management within the social sciences and humanities (SSH) domain, as well as decision-making and mathematics within the science, technology, engineering, and mathematics (STEM) domain. The SSH researchers specialised in urban logistics in this study built a narrative scenario to facilitate the participants' understanding towards this cargo bike delivery topic. The STEM researchers specialised in group decision-making applied the Multicriteria Satisfaction Analysis (MUSA) methodology for data analysis. Meanwhile, the online questionnaire design, dissemination, contents and results were compiled together.

In this chapter, we present a novel technique for eliciting preferences to facilitate sustainable logistics policy development. We apply a multicriteria decision analysis method, i.e. MUSA, aimed at assessing the opinions of public stakeholders in urban logistics policymaking. We demonstrate its practical usefulness through an empirical study to map the mass public perceptions of cargo bike as a means of last-mile delivery. This methodology seeks to offer a comprehensive understanding of the complexities inherent in urban logistics contexts, drawing upon interdisciplinary insights from both SSH and STEM disciplines.

Research Methods and Survey Design

In this study, we propose an inclusive and intuitive *preference mapping approach* based on the MUSA method to elicit participants' preferences mapping in the policymaking process (Grigoroudis & Siskos, 2002). Mapping the preferences of the public towards services is crucial, as it enables service providers to tailor their offerings to meet the specific needs and expectations of their customers, thereby enhancing satisfaction and fostering sustained engagement (Czepkiewicz et al., 2018). In this context, the MUSA method has been used to precisely map public preferences for a specific service, illustrating its utility in capturing nuanced consumer insights. However, it is usually applied with a rather small sample size (Grigoroudis & Siskos, 2010). In this study, we implemented the MUSA method within a mass-participation scenario with over 2,000 participants.

To illustrate our approach, an evidence-based business case using a "cargo bike delivery service" was developed as a *hypothetical* scenario. Based on this scenario, we developed a MUSA-based framework to obtain and aggregate citizen feedback from multiple cities, incorporating a diverse range of socio-demographic backgrounds, for policy recommendations.

In our MUSA application, participants are asked to express their judgments, including their overall and specific satisfaction level on several criteria towards the hypothetical cargo bike delivery service. A predetermined α level ordinal satisfaction scale is used to capture these judgments, namely "extremely dissatisfied", "somewhat dissatisfied", "neither satisfied nor dissatisfied", "somewhat satisfied", and "extremely satisfied". This scale facilitates the quantification of customer feedback. In MUSA, the overall satisfaction function is represented by Y^*, while the partial satisfaction functions corresponding to each individual criterion i are denoted by X_i^*. In this study, the criteria are factors that influence citizens' satisfaction and the overall effectiveness of the cargo bike delivery service like CO_2 emissions, noise etc. The relationship between these variables is explained by an ordinal regression analysis equation:

$$Y^* = \sum_{i=1}^{n} b_i X_i^*,$$

$$\sum_{i=1}^{n} b_i = 1,$$

where b_i is the weight of criterion i. Drawing upon the specified equation, MUSA constructs a Linear Programming model designed to discern how satisfaction across multiple criteria contributes to overall satisfaction with the service with the objective of minimising estimation errors derived from participants' inputs. The MUSA output presents a comprehensive set of results, including the overall satisfaction, which is aggregated by partial satisfaction for individual criteria with the respective weights of these criteria. A series of optimisations is performed following the initial one to infer the value functions on criteria and at the global level that better represent the citizen satisfaction. This method ensures that the derived weights are robust, accurately reflecting the priorities of the participants. Additionally, MUSA yields a series of indices, which offer deeper insights, enhancing the interpretability and reliability of the satisfaction assessment results:

1. **Average Satisfaction Indices (ASI)**: Represent the mean of the global or partial value functions, normalised within the range [0,1].

The higher the value, the higher the satisfaction with the corresponding criteria. ASI is denoted as follows:

$$\mathrm{ASI} = \frac{1}{100}\sum_{m=1}^{\alpha} p^m y^{*m},$$

$$\mathrm{ASI}_i = \frac{1}{100}\sum_{k=1}^{a} p_i^k x_i^{*k}, \text{ for } i = 1, 2, \ldots, n,$$

where p^m and p_i^k are the frequencies of customers belonging to the overall satisfaction level and partial satisfaction levels on criterion i, respectively.

2. **Average Demanding Indices (ADI)**: The average demanding indices are normalised in the interval [−1,1]. If the index reaches a value of 1, it indicates that participants exhibit the highest level of demand. In this scenario, participants are only satisfied with the utmost quality level. On the other hand, an index value of −1 signifies the lowest level of demand, where participants have minimal expectations or demands from the service or product in question. ADI is denoted as follows:

$$\mathrm{ADI} = \frac{1 - \frac{\overline{\overline{y}}^*}{50}}{1 - \frac{2}{\alpha}}, \text{ for } \alpha > 2,$$

$$\mathrm{ADI}_i = \frac{1 - \frac{\overline{\overline{x}}^*}{50}}{1 - \frac{2}{\alpha}}, \text{ for } \alpha > 2, \text{ and } i = 1, 2, \ldots, n,$$

where $\overline{\overline{y}}^*$ and $\overline{\overline{x}}^*$ are the mean values of functions Y^* and X_i^*

3. **Average Improvement Indices (AII)**: These indices are normalised in the interval [0,1]. The improvement index for a given criterion is inversely proportional to its performance level, given a certain weight. Specifically, a higher weight assigned to a criterion, coupled with lower performance in that area, results in a correspondingly higher improvement index for that criterion. This relationship highlights areas requiring enhanced focus for improvement, based on their significance and current performance levels:

$$I_i = b_i(1 - \mathrm{ASI}_i), \text{ for } i = 1, 2, \ldots, n.$$

Upon conducting a thorough literature review, we have identified the following key criteria relevant to our study. The survey questions were designed based on each criterion (as listed in Table 10.1).

Research Finding

We surveyed with a computer-assisted web interviewing method in five capital cities in Europe, namely London, Paris, Rome, Dublin, and Warsaw. These capital cities are varied in their urban "freightscape" in terms of population and employment densities (Rodrigue et al., 2017; Rose et al., 2017). Therefore, it would be interesting to explore citizens' perceptions of cargo bike delivery in different urban archetypes.

The target survey participants are the general population over 18 years old residing in these cities. All the surveys were published in English, with additional translations available in French, Italian, and Polish. The data collection was conducted from November 2023 to January 2024.

As a result, a total of 2,030 responses were obtained across five cities (Huang et al., 2024). A statistically significant difference has been observed between urban and suburban samples in London. Consequently, we applied MUSA separately to the urban and suburban samples within London. For the other cities, the MUSA was applied to the combined samples without distinction. Due to the limited size of the suburban sample in Warsaw, we proceed by analysing the entire Warsaw dataset as a single group.

Based on the geographical locations, we clustered participants' responses into 6 groups, namely urban London ($n = 528$), suburban London ($n = 185$), Paris ($n = 545$), Rome ($n = 527$), Dublin ($n = 167$), and Warsaw ($n = 78$). The clustered responses were then analysed using MUSA to derive satisfaction value functions for each area.

Citizens in all five capital cities were highly supportive of the hypothetical introduction of cargo bike delivery services, demonstrating a growing demand for environmentally friendly last-mile delivery solutions. Surveys consistently showed high levels of satisfaction, reflecting appreciation for the overall value proposition of the hypothetical sustainable cargo bike delivery service.

In the post-optimality analysis phase, we compared the performance of the cargo bike service across 5 key criteria. We calculated the associated ASIs, ADIs, and AIIs. Using these indices along with the criteria weights, we developed two types of recommendation diagrams: the *action*

Table 10.1 Key criteria and survey questions

Criterion	*Code*	*Description and Survey Question*
CO_2 emissions	c_1	Electric cargo bike delivery can reduce CO_2 emissions by 30–55% per package (Carracedo & Mostofi, 2022). Cargo bikes can significantly reduce CO_2 emissions and air pollution (such as particulate matter and nitrogen oxide) compared to fossil-fuel vehicles. By transitioning to our e-cargo bikes, we project our reduction of carbon emissions by 70–90% compared to diesel vans, and by a third compared to electric vans Q_1: How satisfied do you feel with this scenario?
Noise	c_2	Quieter operation, less noise for your parcel delivery. Our cargo bikes are designed to be especially quieter than motorcycles or mopeds, with an average of 50–60 dB of noise, making our delivery operations less disruptive in urban areas Q_2: How satisfied do you feel with this scenario?
Traffic	c_3	Cargo bikes can significantly reduce congestion in cities. Given the compact size of our cargo bikes, we anticipate a 75% reduction in the road space required for our cargo bike fleet compared to a normal car (Cairns & Sloman, 2019). Using cargo bikes will allow our package delivery workers to work more efficiently while reducing the number of motorised vehicles in the city (Llorca & Moeckel, 2021) Q_3: How satisfied do you feel with this scenario?
Safety	c_4	Improved safety for pedestrians, and less disturbance from parcel delivery activities. While ensuring the health and safety conditions for our workers using e-cargo bikes to deliver your parcel, given the slower operational speeds (maximum of 25 km/h) (Gonzalez-Calderon et al., 2022) and reduced number of delivery vans blocking roads, cycle paths and pavements, we predict a significant reduction in the number and severity of traffic accidents related to deliveries in the city Q_4: How satisfied do you feel with this scenario?
Shipping cost	c_5	Better working conditions for our riders, but slightly more expensive for your shipping cost. With the commitment to offer fair and qualitative jobs for our e-cargo bike riders, customers may expect a slight 10–20% increase in the delivery fee compared to traditional delivery services Q_5: How satisfied do you feel with this scenario?
Overall satisfaction	v	Q_6: Considering all the above-mentioned information together, how satisfied do you feel with our e-cargo bike delivery option?

and *improvement* diagrams (see both in Fig. 10.1). The action diagram, leveraging weights and ASIs as determined by MUSA, pinpoints priorities for enhancement. The improvement diagram, incorporating AIIs and ADIs, identifies the scope and magnitude of potential improvements.

Unlike traditional applications of MUSA, our study aims to present a holistic overview by integrating action-related metrics of different areas into a single action diagram and improvement diagram. This approach provides a comprehensive, bird's-eye view for recommendations, based on the relative performances across all areas. It is important to note that these recommendations are based on comparative performances, as illustrated in the diagrams where the axes' cutoff levels are recalculated to represent the centroid of all data points.

The overall relative action diagram (Fig. 10.1) organises results into four categories, based on how well different aspects of the cargo bike service are performed (ASIs) and how important these aspects are to citizens (weights):

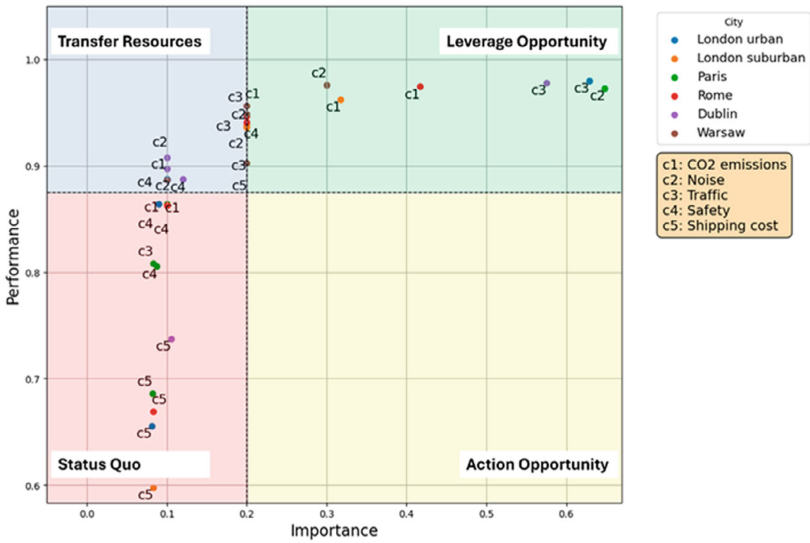

Fig. 10.1 MUSA overall relative action diagram

- *Status Quo:* Identified by low performance and low importance, indicating areas where current performance meets expectations, rendering intervention unnecessary.
- *Leverage Opportunity:* Characterised by high performance and high importance, signalling strengths that could be capitalised on as competitive advantages.
- *Transfer Resources:* Denotes high performance but low importance, suggesting a potential misallocation of resources that could be optimised.
- *Action Opportunity:* Marked by low performance yet high importance, highlighting critical areas needing urgent improvement.

The analysis of citizen feedback from all five cities shows a consistently high level of satisfaction with the cargo bike service. Notably, no criteria are identified as both high importance and low performance, suggesting no immediate need for action. However, this result indicates an opportunity to focus on areas where the cargo bike service has a competitive advantage. For example, in urban London and Dublin, where traffic is perceived as a significant problem, citizens believe that the cargo bike service could effectively reduce traffic congestion. Meanwhile, in Paris and Warsaw, the focus is on noise reduction, with the cargo bike service seen as a beneficial solution to reduce noise pollution. For Warsaw, Rome and the suburb of London, the focus shifts to the importance of reducing CO_2 emissions, where the cargo bike service is seen as a valuable tool of decarbonisation. Conversely, the shipping costs associated with the cargo bike service are perceived as underperforming in all the cities. This suggests a need for strategic evaluation and possible adjustment of the pricing structure. In urban London and Dublin, where traffic is perceived as a significant problem, citizens believe that the cargo bike service could effectively reduce traffic congestion.

The overall relative improvement diagram (Fig. 10.2) is split into four parts, based on two key factors: how much customers are asking for a change (ADI) and how effective our efforts could be (AII):

- *First Priority:* Criteria in this section are characterised by high demand and high effectiveness. This section is where we see values (i.e. sustainability criteria) that citizens most desire and will be most impactful if adopted, yet, aren't too hard to implement.

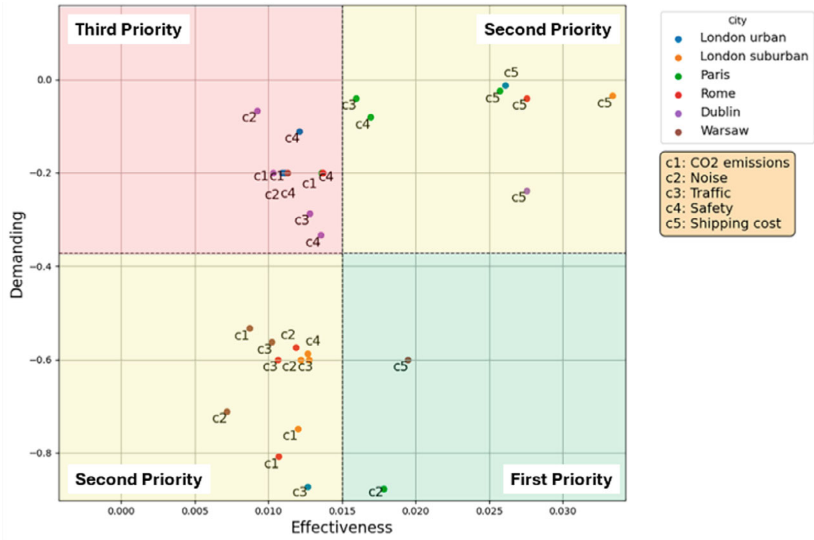

Fig. 10.2 MUSA overall relative improvement diagram

- *Second Priority*: Criteria in this area denote either high demand and low effectiveness, or low demand and high effectiveness. These areas require a balanced approach, which means, the policymakers need to decide carefully where to put resources.
- *Third Priority*: Characterised by low demand and low effectiveness. This last part points out areas that might not be worth the immediate effort because they don't make a huge difference right now and are tough to tackle.

This improvement diagram provides key insights into each city's areas that need improvement. For example, in Warsaw, the shipping cost emerges as a primary concern, highlighting it as a top priority area for improvement. On the contrary, noise reduction is a top priority in Paris. In both cases, these concerns are characterised by a low level of demand from citizens but offer significant room for improvement.

It is also evident that the **delivery cost** for sustainable cargo bike delivery services remains a shared concern for all surveyed citizens across all five cities. In contrast, issues such as **traffic and noise**, while less prioritised by citizens, present challenges in terms of effective improvement. Although preferences vary between cities for different criteria, **safety** stands out as a high-demand criterion in all cities. However, safety appears to be a difficult criterion to improve effectively. This suggests the need for targeted strategies to address safety concerns while considering the inherent difficulties in making substantial improvements in this area.

Conclusion and Policy Recommendations

This study demonstrated the necessity of SSH-STEM collaboration among researchers. Drawing upon SSH researchers' knowledge of cargo bike adoption in urban logistics, an evidence-based hypothetical case scenario was constructed for the MUlticriteria Satisfaction Analysis (MUSA) method application. Leveraging the STEM researchers' expertise in and optimisation statistics, the MUSA method was chosen as a tool to analyse citizens' preferences towards a proposed sustainable solution. This chapter provides new insights to the scholarship on last-mile delivery on the preferences for cargo bike delivery. Our empirical findings suggested that citizens in the selected European capital cities value environmentally sustainable last-mile delivery options. This has echoed the findings from Caspersen and Navrud (2021) that consumers care about the environmental impacts of the last-mile delivery they generate. Moreover, previously mentioned delivery cost for sustainable cargo bike delivery services remains a shared concern for all surveyed citizens. This finding provides a more nuanced understanding of the willingness-to-pay for an alternative last-mile delivery concept (Hagen & Scheel-Kopeinig, 2021) across different cities.

The MUSA-based survey tool offers an alternative approach to gauge public opinions in sustainable logistics policy decision-making. Stakeholder engagement is an integral part of the European Union's sustainable logistics policy framework. The EU promotes public participatory processes and has developed regulatory frameworks, guidelines, and tools to ensure effective stakeholder involvement and increase policy legitimacy (van der Linde et al., 2021). One of the challenges to engaging citizens and consumers in urban logistics policy consultation is to provide sufficient information for the participants in a limited time and space (Tuomala et al., 2023). To overcome this challenge, in this study, to engage citizens from different cities and cultural backgrounds to participate in the same policy evaluation on sustainable cargo bike delivery, we created an evidence-based hypothetical scenario of a cargo bike delivery service to make it easy and accessible for the general population to partake. The MUSA survey procedure is easy and straightforward, facilitating participants in the effortless completion of their responses.

The MUSA-based public perception survey tool proposed in this study offers a methodological guideline for mobility and logistics policymakers (such as the national transport department, local authorities, transport planners), allowing them to map the public's perception and attitude towards sustainable last-mile delivery solutions. Different from the traditional survey descriptive analysis, the MUSA analysis produces the "action diagram and improvement matrix diagram" as the key output of this policy tool (as in Fig. 10.2). The diagram offers a bird's-eye view of the citizens' sustainability prioritisation towards the hypothetical cargo bike delivery service. The matrix diagram can capture areas that require improvement for each city. Moreover, this model considers citizens' perspectives and specific needs in cities of varying scales, making its recommendations both transferable and scalable. The adaptability of this survey tool can be applied across a wide range of scenarios, enhancing the effectiveness of sustainable last-mile delivery solutions.

Different cities have different sustainability priorities when it comes to the sustainable urban freight transport. City managers and logistics practitioner could offer tailored policies and market proposition to address citizens' needs. Reducing carbon emissions as a sustainable goal has been demonstrated by citizens of all cities, but it was not shown as the top priority. For example, by choosing sustainable cargo bike delivery services, citizens in London and Dublin hope to ease the traffic congestion; citizens from Paris and Warsaw hope to reduce the noise. The MUSA Average Satisfaction Indices help to visualise and prioritise the perception and attitudes of citizens towards sustainable last-mile delivery initiatives, thus providing evidence-based support for local authorities and city managers alike to gauge a more nuanced view of their community and neighbourhood.

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