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The Implementation of Low Emission Zones in Low-Income Countries: A Case Study

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ABSTRACT

This paper provides a fuzzy logic approach with multi-stakeholder decision support to evaluate and rank different strategies as well as policies that may have a direct impact on the implementation of low emission zones in low income and developing countries. The multi decision-making analysis, which was performed using the Delphi method and fuzzy logic and applied on the city of Amman, suggested that promoting and investing in last-mile delivery solutions, such as electric vehicles and cargo bikes has the highest impact on implementing low emission zones in Amman and this strategy could increase the sustainability. According to local decision makers, encouraging and investing in last-mile delivery alternatives, such as EVs and cargo bikes, has the most impact on adopting LEZ in Amman's inner city.

Keywords: low emission zones, fuzzy logic, policy analysis.

INTRODUCTION

Urban freight operations entails the movement of goods and services in urban areas (Amaya et al. 2021), positioning it as an essential component of transport sector with a direct impact on stimulating economic and trading activities, the competitiveness between different industries (Browne et al. 2005b), and the social development in urban areas (Dugundji et al. 2011). However, it also imposes negative environmental impacts, such as noise, pollution, and greenhouse gas emissions (Russo and Comi 2012). Therefore, there is a necessity to move towards sustainability to reduce these negative impacts, while maintaining economic and social development.

The sustainability in urban transport is defined based on six principles; contribution to economic growth and economic efficiency, liveable streets and neighbourhoods, equity and social inclusion, protection of the environment and safety (May et al. 2001). Moving toward sustainable urban freight operations should consider the different transportation modes, combinations, and the distribution channels (Al-dalain and Celebi 2021; Taghvaee et al. 2022). Thus, the determination of freight operation sustainability is a strategic decision-making problem that needs the coordination of different parties, such as city planners, decision makers, investors, and governments.

Inner cities can offer a competitive advantage to different businesses that benefit from proximity to strategic locations, transportation infrastructure, in addition to tourist and entertainment centres. In recent years, urban freight operation and home delivery has increased dramatically and become even more critical due to the customers' shift to online shopping, and population growth, especially in developing countries (Foltyński 2014; Zhou et al. 2016). However, freight operations within the inner cities face many challenges related to the nature of the inner city, traffic congestion and the high density of delivery points.

In an effort to increase the sustainability in last-mile deliveries, a strategy must be implemented in city centres. One of the potential solutions that have gained interest is the implementation of low emission zones (LEZs), whereby LEZs restrict certain types of vehicles from entering specific zones based on the amount of CO_2 emissions they produce (Cruz and Montenon 2016). According to (Gehrsitz 2017) low emission zones are considered as one of the most aggressive policy measures used to reduce air pollution and increase public health. Implementing low emission in inner cities is a complex decision and influenced by several factors. These include economic factors (Börjesson et al. 2021), social factors (De Vrij and Vanoutrive 2022), and environmental factors (Tarriño-Ortiz et al. 2022).

According to (Behrends et al. 2008) a sustainable transport sector must contribute to three fundamental components of sustainable development: (1) environment by reducing the negative impact of transport system air pollution, greenhouse gas emissions, noise, health, safety, (2) economic growth by improvement of the efficiency and cost-effectiveness of the transportation of persons and goods. (3) Social equity by ensuring the accessibility offered by the transport system. Several strategies have been used to increase the awareness of sustainability in freight transportation sector, such as: using electric vehicles (Aldalain and Celebi 2021), establishing urban consolidation centres (Simoni et al. 2018), road pricing (Quak et al. 2016), low emission zones (Cruz and Montenon 2016), loading/unloading (Imane and Fouad 2019), and time window (Holguín-Veras et al. 2020).

Deveci et al. (2022)an integrated two-stage decision analysis approach is proposed. In the first stage, the Defining Interrelationships Between Ranked criteria (DIBR proposed a novel methodology to achieve and sustain low emission urban freight transportation, where they integrate Combined Compromise Solution (CoCoSo) with the context of type-2 neutrosophic numbers to identify the most optimal sustainable urban logistics alternative. To calculate the weights, the authors used the Defining Interrelationships between Ranked criteria (DIBR) method. Browne et al. (2005a) studied the likely effects of low emission zones on the freight transport sector in London. According to authors, LEZ would help in increasing the adoption rate of cleaner vehicles, and reduce the number of older, more polluting vehicles operating in London. Savadogo et al. (2023) developed a new methodology to investigate the environmental and the economic impact of low emission zones for freight vehicles in the city of Lyon. The methodology is composed of three main stages: at the first stage, a simulation of transport demand, supply and organisation is performed, followed by economic and environmental calculations; at the last stage, cost-benefit analysis for a five-year period is performed.

Broaddus et al. (2015) investigated the impact of freight operations considering low emission zones and congestion charge zones in the city of London taking into consideration such factors as rerouting, retiming, number of trips, distance, and vehicles. The results indicate that low emission zones are effective in vehicle replacement especially for smaller vehicles. Matusiewicz (2019) determined the main conditions for the implementation of deliveries in the Limited Accessibility Zone (LAZ) in Poland that was created to reduce traffic congestion and carbon dioxide emission in inner cities. In addition, the author specifies guidelines for creating new transport policy for the cities that align with sustainable urban logistics using desk research methods. Ellison et al. (2013) evaluated the impact of London's low emission zone on the registration and usage of vehicles and air pollution. The results indicate that the LEZ has a substantial effect on the vehicle fleet composition, where the replacement rate for older vehicles has increased. In addition, the results indicate that LEZ has an effect on the usage of vehicles with light commercial vehicles constituting the majority of vehicles used in London, mostly at the expense of rigid vehicles. Dablanc and Montenon (2015) conducted a thorough literature review, interviews, and surveys in different cities to specify the impact of LEZ on logistics firms and on their logistics activities.

Peters et al. (2021) analysed the effect of low-emission zones on the usage of alternative vehicles and its effectiveness for reducing the CO_2 emissions in Madrid. For this purpose, the authors proposed a three-staged approach; first determining whether the LEZ triggered a significant increase in AFV registration, then determining the actual CO_2 emissions from all newly private passenger vehicles. Finally, quantifying the greenhouse gas emissions reduction resulting from introducing LEZ. Santos et al. (2019) evaluated the air quality improvements due to the implementation of low emission zones in the city of Lisbon from 2009 to 2016 by examining the temporal trend of different emissions concentrations and evaluating the exceedances to legislated limits. The results obtained from the implementation of LEZ showed a positive improvement in air quality when comparing the period between 2009 and 2016. Gehrsitz (2017) investigated the benefits of implementing low emission zones in terms of improvements in air pollution and infant health at different points in time in different cities throughout Germany. Carslaw and Beevers (2002) evaluated two principal types of LEZ; the reduction of vehicle flows and the restriction of certain (higher emitting) vehicle types in central London. The authors developed empirical prediction models to predict the annual mean nitrogen dioxide concentrations utilising comprehensive traffic data and air pollution measurements. The results show that reduction of emission from road traffic through LEZs has the potential to reduce the emission concentrations close to roads in central London.

There are several strategies and practices that have a direct impact on the implementation of LEZs in developing countries using decision making techniques, then investigating and ranking these strategies based on a fuzzy logic approach that was developed by (Wang 2015). Fuzzy logic approach was used to overcome the uncertainty, since fuzzy set theory is able to handle the uncertainty associated with multi criteria decision problem (Fu, 2008).

The goal of this paper was to identify the main strategies and policies that help in implementing low emission zones in inner cities in low-income countries, since these countries often face unique challenges that require tailored solutions that commensurate with its nature, economic and environmental status.

METHODOLOGY

Delphi method was applied to reach consensus about the main strategies that have a direct impact on implementing the LEZs in low income and developing countries since these countries often face unique challenges that require tailored solutions that commensurate with its nature, economic and environmental status. The Delphi method is a method that is used to achieve convergence of opinion concerning complex problems among different experts in the field of interest (Dalkey and Helmer 1963; Linstone and Turoff 2011; Hsu and Sandford 2019). Therefore, a group of experts and decision-makers was identified. The participants were selected among city planners, stakeholders, service providers, and academic researchers. Then, the Delphi method process was conducted in rounds. In each round, the experts provide their assessment based on linguistic terms on the various strategies. After each round, analysis was performed to obtain feedback. The process was repeated until a consensus was reached.

In the third stage, a fuzzy logic method developed by (Wang 2015) was performed. The method was designed to measure the fuzzy preference relation between triangular fuzzy numbers, where according to authors ranking fuzzy numbers by the relative preference relation is similar to defuzzification on fuzzy operation (Wang 2015). At the beginning, linguistic terms were transformed into fuzzy numbers using scale (0, 10) as shown in Table 1.

Then, set $S = \{X_1, X_2, \ldots, X_n\}$, was used to indicate a set consisting of n triangular fuzzy numbers, where $X_i = (X_{il}, X_{im}, X_{ir})$, where $i = 1, 2, .., n$. Now, let $(\bar{X}) = (\bar{X}_{il}, \bar{X}_{im}, \bar{X}_{ir})$, be average of the n fuzzy numbers. The relative preference relation P^* with membership function $\mu_p(X_i, \bar{X})$ represents the preference degree of X_i over $\bar{X}$ in S is calculated using the Equation (1) and (2) (Wang 2015).

Finally $\mu_p(X_i, \bar{X})$, according to the values of for the chosen indicators. The ranking results are obtained. Figure 1 illustrates the different stages of the presented methodology.

Table 1. Linguistic variable for the importance weight of each strategy

Very Low (VL)	(0, 0, 1)
Low (L)	(0, 1, 3)
Medium Low (ML)	(1, 3, 5)
Medium (M)	(3, 5, 7)
Medium High (MH)	(5, 7, 9)
High (H)	(7, 9,10)
Very High (VH)	(9,10,10)

$$\mu_{\boldsymbol{P}^*}(X_i,\bar{X}) = \frac{1}{2}\left(\frac{(X_{il}-\bar{X}_r)+2(X_{im}-\bar{X}_m)+(X_{ir}-\bar{X}_l)}{2\parallel T_S\parallel}+1\right) \tag{1}$$

where:

$$\parallel T_S \parallel = \begin{cases} \dfrac{({t_{sl}}^{+}-{t_{sr}}^{-})+2({t_{sm}}^{+}-{t_{sm}}^{-})+({t_{sr}}^{+}-{t_{sl}}^{-})}{2} & if\ {t_{sl}}^{+} \geq {t_{sr}}^{-} \\ \dfrac{({t_{sl}}^{+}-{t_{sr}}^{-})+2({t_{sm}}^{+}-{t_{sm}}^{-})+({t_{sr}}^{+}-{t_{sl}}^{-})}{2}+2({t_{sr}}^{-}-{t_{sl}}^{+}) & if\ {t_{sl}}^{+} < {t_{sr}}^{-} \end{cases} \tag{2}$$

where: $t_{sl}^{+} = max_i\{X_{il}\}$, $t_{sm}^{+} = max_i\{X_{im}\}$, $t_{sr}^{+} = max_i\{X_{ir}\}$, $t_{sl}^{-} = min_i\{X_{il}\}$, $t_{sm}^{-} = \min_i\{X_{im}\}$, $t_{sr}^{-} = min_i\{X_{ir}\}$, for $i = 1, 2, \ldots, n$.

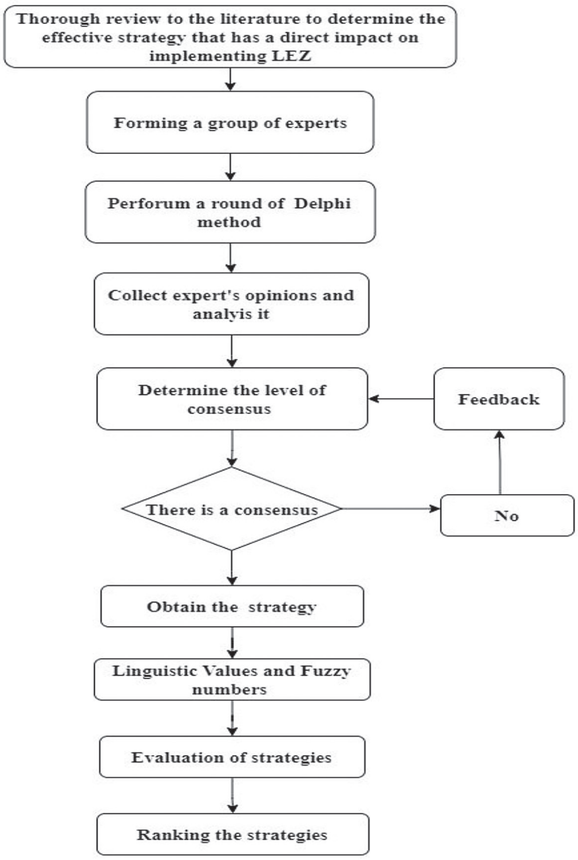

Figure 1. The presented methodology

CASE STUDY

To demonstrate the applicability of the proposed methodology, a case study from the city of Amman, the capital city of Jordan, is investigated. Jordan is a developing country because of its lower middle income economic performance (Rodriguez and Wai-Poi; The World Bank 2020; Hamadeh et al. 2023). The transportation system in the inner city of Amman varies between private cars, bus rapid transit (BRT), public buses of various sizes, and taxis (Al-Dalain and Alnsour 2022). The inner city is densely populated, resulting in congested roads that make it even more difficult for residents and tourists to walk comfortably in the city centre. This also leads to increased levels of noise and pollution, hindering the efforts to make Amman a sustainable city. In recent years, Jordan has started adopting the strategies and applying the measures to increase the sustainability, especially in the transport sectors.

A series of iterative questionnaires was performed to determine which of these strategies have a direct impact on LEZ in Amman, where a panel of experts provided anonymous responses with respect to the strategies and measures that

Table 2. Strategies and measures

ID	Strategies and measures
S1	Promote and invest in last-mile delivery solutions, such as EVs and cargo bikes.
S2	Improve and expand public transportation options allowed inside the LEZ.
S3	Increase public acceptance and awareness.
S4	Engage other polices beside LEZ such as Delivery Time Windows and loading/unloading.
S5	Establish regulations such as emission standards and penalties.
S6	Invest in the necessary technological infrastructures.
S7	Engage and facilitate collaboration between stakeholders, decision makers, experts, and local authorities.
S8	Introduce incentives for freight operators adopting environmentally friendly practices.
S9	Establish micro consolidation centres for freight operations inside LEZ.
S10	Implement the low-emission zones gradually.
S11	Enhance the travel infrastructure around a Low Emission Zone.
S12	Conduct a comprehensive cost-benefit analysis for local small businesses inside LEZ.
S13	Develop a dynamic pricing model for peak and off-peak delivery time.

were obtained from the first stage. In each round, feedback from the experts were received and analysed until a convergence of opinion on the main strategies that has a direct impact on the implementation of LEZs in the inner city of Amman was obtained, as illustrated in Table 2.

Next, a diverse group of experts were engaged in the assessment process to ensure a comprehensive understanding to the topic. This includes 5 academics: two specialised in city planning, another two with expertise in transportation infrastructure and one on freight operations. In addition, consultation with four government experts was very crucial, including those who are informed on the consequences of implementing regulations and policies. This collaborative approach ensured a well assessment and in depth exploration of the implementation of low emission zones in Jordan.

RESULTS

A set of experts were enlisted to assess the strategies and measures using linguistics terms based on a predefined scale from Table 1. The results are illustrated in Table 3. Then, the linguistic terms were converted into fuzzy terms as illustrated in Table 1, the results are presented in Table 4. Then, for each strategy the weights of all

Table 3. The assessment of each strategy with respect to each decision-makers

ID	Strategies and measures	D1	D2	D3	D4	D5	D6	D7	D8	D9
S1	Promote and invest in last-mile delivery solutions, such as EVs and cargo bikes.	VH	H	VH	M	L	H	H	VH	MH
S2	Improve and expand public transportation options allowed inside the LEZ.	H	VH	MH	H	M	MH	L	ML	M
S3	Increase public acceptance and awareness.	M	M	M	VH	ML	ML	M	ML	H
S4	Engage other polices beside LEZ such as Delivery Time Windows and loading/unloading.	L	H	M	L	M	M	H	MH	M
S5	Establish regulations such as emission standards and penalties.	H	MH	ML	MH	H	ML	M	H	MH
S6	Invest in the necessary technological infrastructures.	MH	M	M	L	M	ML	L	VL	ML
S7	Engage and facilitate collaboration between stakeholders, decision makers, experts, and local authorities.	ML	H	VH	H	MH	M	L	ML	M
S8	Introduce incentives for freight operators adopting environmentally friendly practices.	VL	M	L	L	VL	VL	H	M	ML
S9	Establish micro consolidation centres for freight operations inside LEZ.	VL	ML	L	VL	L	ML	MH	L	VL
S10	Implement the low-emission zones gradually.	ML	L	VL	M	ML	VL	M	ML	L
S11	Enhance the travel infrastructure around a Low Emission Zone.	VH	H	H	ML	H	VH	L	M	H
S12	Conduct a comprehensive cost-benefit analysis for local small businesses inside LEZ.	VL	MH	ML	M	M	ML	L	VL	ML
S13	Develop a dynamic pricing model for peak and off-peak deliveries.	H	MH	MH	H	ML	M	M	ML	VL

Table 4. The assessment of each strategy with respect to each decision-makers using Fuzzy numbers

ID	D1	D2	D3	D4	D5	D6	D7	D8	D9
S1	(0.9,1,1)	(0.7,0.9,1)	(0.9,1,1)	(0.3,0.5,0.7)	(0,0.1,0.3)	(0.7,0.9,1)	(0.7,0.9,1)	(0.9,1,1)	(0.5,0.7,0.9)
S2	(0.7,0.9,1)	(0.9,1,1)	(0.5,0.7,0.9)	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0,0.1,0.3)	(0.1,0.3,0.5)	(0.3,0.5,0.7)
S3	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.9,1,1)	(0.1,0.3,0.5)	(0.1,0.3,0.5)	(0.3,0.5,0.7)	(0.1,0.3,0.5)	(0.7,0.9,1)
S4	(0,0.1,0.3)	(0.7,0.9,1)	(0.3,0.5,0.7)	(0,0.1,0.3)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.5,0.7,0.9)
S5	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.1,0.3,0.5)	(0.5,0.7,0.9)	(0.1,0.3,0.5)	(0.1,0.3,0.5)	(0.3,0.5,0.7)	(0.7,0.9,1)	(0.5,0.7,0.9)
S6	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0,0.1,0.3)	(0.3,0.5,0.7)	(0.1,0.3,0.5)	(0,0.1,0.3)	(0,0,0.1)	(0.1,0.3,0.5)
S7	(0.1,0.3,0.5)	(0.7,0.9,1)	(0.9,1,1)	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0,0.1,0.3)	(0.1,0.3,0.5)	(0.3,0.5,0.7)
S8	(0,0,0.1)	(0.3,0.5,0.7)	(0,0.1,0.3)	(0,0.1,0.3)	(0,0,0.1)	(0,0,0.1)	(0.7,0.9,1)	(0.3,0.5,0.7)	(0.1,0.3,0.5)
S9	(0,0,0.1)	(0.1,0.3,0.5)	(0,0.1,0.3)	(0,0,0.1)	(0,0.1,0.3)	(0.1,0.3,0.5)	(0.5,0.7,0.9)	(0,0.1,0.3)	(0,0,0.1)
S10	(0.1,0.3,0.5)	(0,0.1,0.3)	(0,0,0.1)	(0.3,0.5,0.7)	(0.1,0.3,0.5)	(0,0,0.1)	(0.3,0.5,0.7)	(0.1,0.3,0.5)	(0,0.1,0.3)
S11	(0.9,1,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.1,0.3,0.5)	(0.7,0.9,1)	(0.7,0.9,1)	(0,0.1,0.3)	(0.3,0.5,0.7)	(0.7,0.9,1)
S12	(0,0,0.1)	(0.5,0.7,0.9)	(0.1,0.3,0.5)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.1,0.3,0.5)	(0,0.1,0.3)	(0,0,0.1)	(0.1,0.3,0.5)
S13	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.7,0.9,1)	(0.1,0.3,0.5)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.1,0.3,0.5)	(0,0,0.1)

Table 5. The aggregated weight

ID	Strategies and measures	Aggregate decision makers weights
S1	Promote and invest in last-mile delivery solutions, such as EVs and cargo bikes.	(0.622,0.78,0.87)
S2	Improve and expand public transportation options allowed inside the LEZ.	(0.467,0.64,0.8)
S3	Increase public acceptance and awareness.	(0.34,0.53,0.7)
S4	Engage other polices beside LEZ such as Delivery Time Windows and loading/unloading.	(0.367,0.54,0.72)
S5	Establish regulations such as emission standards and penalties.	(0.389,0.54,0.77)
S6	Invest in the necessary technological infrastructures.	(0.178,0.33,0.52)
S7	Engage and facilitate collaboration between stakeholders, decision makers, experts, and local authorities.	(0.4,0.58,0.73)
S8	Introduce incentives for freight operators adopting environmentally friendly practices.	(0.156,0.267,0.42)
S9	Establish micro consolidation centres for freight operations inside LEZ.	(0.077,0.177,0.34)
S10	Implement the low-emission zones gradually.	(0.1,0.23,0.4)
S11	Enhance the travel infrastructure around a Low Emission Zone.	(0.53,0.71,0.83)
S12	Conduct a comprehensive cost-benefit analysis for local small businesses inside LEZ.	(0.156,0.278,0.478)
S13	Develop a dynamic pricing model for peak and off-peak deliveries.	(0.355,0.53,0.7)

Table 6. Strategies ranking

ID	Strategies and measures	Importance	Ranking
S1	Promote and invest in last-mile delivery solutions, such as EVs and cargo bikes.	1.000267	1
S2	Improve and expand public transportation options allowed inside the LEZ.	0.781273	3
S3	Increase public acceptance and awareness.	0.587431	8
S4	Engage other polices beside LEZ such as Delivery Time Windows and loading/unloading.	0.616485	6
S5	Establish regulations such as emission standards and penalties.	0.647708	5
S6	Invest in the necessary technological infrastructures.	0.265661	9
S7	Engage and facilitate collaboration between stakeholders, decision makers, experts, and local authorities.	0.669825	4
S8	Introduce incentives for freight operators adopting environmentally friendly practices.	0.158116	11
S9	Establish micro consolidation centres for freight operations inside LEZ.	0.011108	13
S10	Implement the low-emission zones gradually.	0.093068	12
S11	Enhance the travel infrastructure around a Low Emission Zone.	0.882314	2
S12	Conduct a comprehensive cost-benefit analysis for local small businesses inside LEZ.	0.192808	10
S13	Develop a dynamic pricing model for peak and off-peak deliveries.	0.593936	7

decision makers were aggregated (Table 5) with respect to the three dimensions using the following equation:

$$x_{ij}^{D} = \frac{1}{D}\left(x_{ij}^{1} + x_{ij}^{2} + \cdots + x_{ij}^{D}\right) \quad (3)$$

To illustrate the aggregation, let us take the first strategy as example:

(0.9+0.7+0.9+0.3+0+0.7+0.7+0.9+0.5)/6 = 0.62

(1+0.9+1+0.5+0.1+0.9+0.9+1+0.7)/6 = 0.78

(1+1+1+0.7+0.3+1+1+1+0.9)/6 = 0.87

Thus, the aggregation value for the first strategy is (0.62, 0.78, 0.87).

Next, we obtained the average of strategies S_1, S_2, …, S_{13}, which is (0.318, 0.47, 0.637). Likewise, we calculated the value of $\| T_S \|$ of S_1, S_2, …, S_{13}, which was (0.576). In the third step, the relative preference relation P^* with membership function $\mu_{p^*}(X_i, \bar{X})$ was calculated using Equation (1) for each criterion. On the basis of the previous computations, the importance of each strategy is shown in Table 6.

By comparing the membership function $\mu_p(X_i, \bar{X})$ for the different strategies (Table 6), the results show that the "Promote and invest in last-mile delivery solutions, such as EVs and cargo bikes" obtained the highest score by local decision makers. This can be attributed to the high number of firms and business in the inner cities, which make it a high priority to ensure the flow of their goods and services. The second ranked strategy was "Enhance the travel infrastructure around a Low Emission Zone", the rationale for this strategy may be to increase the feasibility of LEZ and make it more accessible for citizens, and thus lead to higher level of public support. It is interesting that the local decision makers did not give a high priority for "Establish regulations such as emission standard and penalties" strategy, and this can be justified to the nature of the low-income countries, where citizen annual income is low and that the citizen will resist low emission zones implementation due to the additional costs. This can also apply to the "Invest in the necessary technological infrastructures" strategy, as the governments in developing countries have a limited budget for city planning and development, they will aim to avoid excessive costs. The presented approach demonstrates how local decision-makers, authorities, and city planners can implement and rank the suitable policies and strategies that aligned with local needs and enhance the sustainability in inner cities.

CONCLUSIONS

A case study from Amman the capital of Jordan was conducted to ensure the applicability of the presented methodology. According to the local decision makers, promoting and investing in last-mile delivery solutions, such as EVs and cargo bikes has the highest impact on implementing LEZ in the inner city of Amman and they could increase the sustainability in the inner city with the highest feasibility and it is easy to adopt and implement. Enhancing the travel infrastructure around a LEZ can also contribute to the implementation thereof. The results provide a good contribution given that no prior studies have assessed these strategies in developing countries.

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REFERENCES

1. Al-dalain R., Alnsour M. 2022. Measuring the sustainability performance of the public transport system: A case of the Amman BRT system in operation. Int J Proj Manag Product Assess, 10: 1–13.
2. Al-dalain R., Celebi D. 2021. Planning a mixed fleet of electric and conventional vehicles for urban freight with routing and replacement considerations. Sustain Cities Soc, 73, 103105.
3. Amaya J., Delgado-Lindeman M., Arellana J., Allen J. 2021. Urban freight logistics: What do citizens perceive? Transp Res Part E Logist Transp Rev, 152: 102390. https://doi.org/10.1016/j.tre.2021.102390
4. Behrends S., Lindholm M., Woxenius J. 2008. The impact of urban freight transport: A definition of sustainability from an actor's perspective. Transp Plan Technol. https://doi.org/10.1080/03081060802493247
5. Börjesson M., Bastian A., Eliasson J. 2021. The economics of low emission zones. Transp Res Part A Policy Pract, 153: 99–114.
6. Broaddus A., Browne M., Allen J. 2015. Sustainable freight impacts of the London congestion charge and low emissions zones. Transp Res Rec, 2478: 1–11. https://doi.org/10.3141/2478-01
7. Browne M., Allen J., Anderson S. 2005a. Low emission zones: the likely effects on the freight transport sector. Int J Logist Res Appl, 8: 269–281.
8. Browne M., Sweet M., Woodburn A., et al. 2005b. Urban Freight Consolidation Centres. Transp Sudies Group, Univ Westminster.
9. Carslaw D.C., Beevers S.D. 2002. The efficacy of low emission zones in central London as a means of reducing nitrogen dioxide concentrations. Transp Res Part D Transp Environ, 7: 49–64. https://doi.org/10.1016/S1361-9209(01)00008-6
10. Cruz C., Montenon A. 2016. Implementation and impacts of low emission zones on freight activities in Europe: Local schemes versus national schemes. Transp Res Procedia,12: 544–556. https://doi.org/10.1016/j.trpro.2016.02.010
11. Dablanc L., Montenon A. 2015. Impacts of environmental access restrictions on freight delivery activities: Example of low emissions zones in Europe. Transp Res Rec, 2478: 12–18. https://doi.org/10.3141/2478-02
12. Dalkey N., Helmer O. 1963. An experimental application of the Delphi method to the use of experts. Manage Sci, 9: 458–467.
13. De Vrij E., Vanoutrive T. 2022. No-one visits me anymore: Low emission zones and social exclusion via sustainable transport policy. J Environ Policy Plan, 24: 640–652. https://doi.org/10.1080/1523908X.2021.2022465

14. Deveci M., Pamucar D., Gokasar I., et al. 2022. An analytics approach to decision alternative prioritization for zero-emission zone logistics. J Bus Res, 146: 554–570. https://doi.org/10.1016/j.jbusres.2022.03.059
15. Dugundji E.R., Páez A., Arentze T.A., et al. 2011. Transportation and social interactions. Transp. Res. Part A Policy Pract, 45: 239–247.
16. Ellison R.B., Greaves S.P., Hensher D.A. 2013. Five years of London's low emission zone: Effects on vehicle fleet composition and air quality. Transp Res Part D Transp Environ 23: 25–33. https://doi.org/10.1016/j.trd.2013.03.010
17. Foltyński M. 2014. Electric Fleets in Urban Logistics. Procedia - Soc Behav Sci, 151: 48–59. https://doi.org/10.1016/j.sbspro.2014.10.007
18. Gehrsitz M. 2017. The effect of low emission zones on air pollution and infant health. J Environ Econ Manage, 83: 121–144. https://doi.org/10.1016/j.jeem.2017.02.003
19. Hamadeh N., Van Rompaey C., Metreau E. 2023. World Bank Group country classifications by income level for FY24 (July 1, 2023 – June 30, 2024). https://blogs.worldbank.org/opendata/new-world-bank-group-country-classifications-income-level-fy24. Accessed 14 Dec 2023
20. Holguín-Veras J., Amaya Leal J., Sanchez-Diaz I., et al. 2020. State of the art and practice of urban freight management Part II: Financial approaches, logistics, and demand management. Transp Res Part A Policy Pract, 137: 383–410. https://doi.org/10.1016/j.tra.2018.10.036
21. Hsu C.-C., Sandford B.A. 2019. The Delphi technique: making sense of consensus. Pract assessment, Res Eval, 12: 10.
22. Imane M., Fouad J. 2019. Proposal methodology of planning and location of loading/unloading spaces for urban freight vehicle: A case study. Adv Sci Technol Eng Syst, 4: 273–280. https://doi.org/10.25046/aj040534
23. Linstone H.A., Turoff M. 2011. Delphi: A brief look backward and forward. Technol Forecast Soc Change, 78: 1712–1719.
24. Matusiewicz M. 2019. Towards sustainable urban logistics: Creating sustainable urban freight transport on the example of a limited accessibility zone in Gdansk. Sustain, 11(14): 3879. https://doi.org/10.3390/su11143879
25. Peters J.F., Burguillo M., Arranz J.M. 2021. Low emission zones: Effects on alternative-fuel vehicle uptake and fleet CO_2 emissions. Transp Res Part D Transp Environ, 95: 102882. https://doi.org/10.1016/j.trd.2021.102882
26. Quak H., Nesterova N., van Rooijen T., Dong Y. 2016. Zero emission city logistics : current practices in freight electromobility and feasibility in the near future. Transp Res Procedia, 14: 1506–1515. https://doi.org/10.1016/j.trpro.2016.05.115
27. Rodriguez L., Wai-Poi M. 2024. Fiscal Policy, Poverty and Inequality in Jordan. Policy Research Working Paper, 10732.
28. Russo F., Comi A. 2012. City characteristics and urban goods movements: A way to environmental transportation system in a sustainable city. Procedia-Social Behav Sci, 39: 61–73.
29. Santos F.M., Gómez-Losada Á., Pires JCM(2019. Impact of the implementation of Lisbon low emission zone on air quality. J Hazard Mater, 365: 632–641. https://doi.org/10.1016/j.jhazmat.2018.11.061
30. Savadogo I., Gardrat M., Koning M. 2023. Environmental and economic evaluation of a low emission zone for urban freight transport. Res Transp Econ, 102: 101369. https://doi.org/10.1016/j.retrec.2023.101369
31. Simoni M.D., Bujanovic P., Boyles S.D., Kutanoglu E. 2018. Urban consolidation solutions for parcel delivery considering location, fleet and route choice. Case Stud Transp Policy, 6: 112–124. https://doi.org/10.1016/j.cstp.2017.11.002
32. Taghvaee V.M., Nodehi M., Saber R.M., Mohebi M. 2022. Sustainable development goals and transportation modes: Analyzing sustainability pillars of environment, health, and economy. World Dev Sustain, 1: 100018.
33. Tarriño-Ortiz J., Gómez J., Soria-Lara J.A., Vassallo J.M. 2022. Analyzing the impact of Low Emission Zones on modal shift. Sustain Cities Soc, 77: 103562.
34. The World Bank 2020. Jordan's Economic Update – April 2020. https://www.worldbank.org/en/country/jordan/publication/economic-update-april-2020
35. Wang Y.J. 2015. Ranking triangle and trapezoidal fuzzy numbers based on the relative preference relation. Appl Math Model, 39: 586–599. https://doi.org/10.1016/j.apm.2014.06.011
36. Zhou L., Wang X., Ni L., Lin Y. 2016. Location-routing problem with simultaneous home delivery and customer's pickup for city distribution of online shopping purchases. Sustainability, 8: 828.