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The assessment model of logistical performance for the road transport network: an Importance–Performance Analysis based on Fuzzy AHP

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Abstract:

The current paper aims at assessing logistical performance for the road transport network by an Importance–Performance Analysis (IPA) based on the Fuzzy Analytic Hierarchy Process (AHP). In doing so, the paper first determines assessment criteria (AC) to evaluate logistical performance for the road transport network on the basis of a literature review, industrial experts' consultation, and the characteristics of road transportation. Next, fuzzy AHP is used to figure out the priority weight for ACs from companies' perspective, including importance and satisfaction weights. Then, the IPA model is deployed to select ACs that should be prioritized the allocation of scarce resources. Finally, enterprises doing business in the Mekong Delta of Vietnam (the MK-VN case) are empirically surveyed to verify the proposed research model.

Keywords: logistical performance, road transport network, Importance–Performance Analysis, Fuzzy AHP

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1. Introduction

In many countries, goods movements from manufacturing areas to consumption destinations heavily rely on the road network. In 2019, approximately 71% of total freight tonnage in the U.S. and around 76% of inland freight transport in the European Union was transported by road. Similarly, road transportation in many Asian countries is an essential mode for freight transport, particularly for short and medium distances. The specific percentage can vary across countries. For example, road transportation in India accounts for around 60-65% of the total freight movement (Ersoy & Tanyeri, 2021). In the meantime, road transport in Vietnam is ranked second just behind maritime, with a total freight capacity of 74.58 billion metric ton-kilometers in 2021 (Zawawi et al., 2017). Nonetheless, evaluating logistical performance for the road transport network, especially in developing nations, has not received much attention from academia and practitioners. Besides, in practice,

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transportation planning authorities in many countries, especially developing or transitional economies, often lack practical frameworks for resource allocation to improve logistical performance based on systematic prioritization (W.-K. Hsu et al., 2023; Nguyen et al., 2022). Accordingly, it is of paramount importance to develop a decision support tool to prioritize key logistics performance indicators (LPIs) for road transport networks. Such a tool is expected to offer concrete insights for infrastructure investment and policy focus.

In addition, evaluating logistical performance of the road transport network is analogous to multiple-criteria decision analysis (MCDA). It has been postulated that the fuzzy Analytic Network Process (ANP) and fuzzy AHP are the most well-known techniques for resolving MCDA problems. More particularly, the former deploys a network-clusters matrix to construct networks of criteria and their relationships, determining priorities, and performing calculations. Meanwhile, the latter relies on pairwise comparisons to evaluate the relative importance of alternatives based on certain criteria or attributes. W. K. Hsu et al. (2023) argued that the complexity of ANP algorithms can make it challenging for many users who are not familiar with mathematical methodologies in decision analysis, thereby restricting its application, especially in a complex system with many criteria and alternatives. In comparison, fuzzy AHP does not require interdependence among criteria; therefore, it provides a simpler and more straightforward approach for hierarchical decision structures. Nevertheless, there is little existing literature on the utilization of fuzzy AHP to evaluate logistical performance for the road transport network.

Furthermore, it has been argued that logistics performance has become a central topic in supply chain and transportation research. Nonetheless, the majority of existing studies only concentrate on port logistics (Hsu & Huynh, 2023; W. K. Hsu et al., 2023), air freight systems (Huang et al., 2025), and multimodal transportation networks (Krasheninin et al., 2022). Most crucially, the emphasis of these sectors on international trade and their integration with global supply chains underrepresents road transport logistics in academic literature and practical assessment models. As noted by some prior studies, the road transport network serves as the critical link between production hubs (Pérez-Martínez et al., 2020), distribution centers (Thu et al., 2024), and end consumers (Özceylan et al., 2016), especially in countries with developing or dispersed infrastructure. Therefore, it can be said that the hybrid IPA and Fuzzy AHP not only captures the multidimensional nature of logistical performance but also accounts for uncertainty and expert judgment.

To fill the literature gap, the present article aims at assessing logistical performance of the road transport network using the IPA model based on Fuzzy AHP. In doing so, the paper first determined the list of ACs to evaluate logistical performance for the road transport network on the basis of a literature review, industrial experts' consultation, and the characteristics of road transportation. Next, fuzzy AHP was adopted to figure out the priority weight for ACs from the companies' perspective, including importance and satisfaction weights. Then, the IPA model was deployed to select ACs that should be prioritized for the allocation of scarce resources. Finally, enterprises doing business in the Mekong Delta of Vietnam (hereafter the MK-VN case) was empirically surveyed to validate the suggested research framework.

The structure of the article is organized as follows. Section 2 presents the literature review on logistical performance for the road transport network. Section 3 is the research methods adopted in this paper. Section 4 displays empirical results and discussions. Finally, Section

5 will then summarize what has been done and point out relevant shortcomings along with possible further lines of development.

2. Literature reviews

To date, logistical performance for the road transport network is defined and measured through some concepts, such as logistical efficiency, convenience, reliability, security and safety, and connectivity. The section below will present a literature review on such concepts to identify insights on their observed items, also known as assessment criteria (ACs).

First, logistical efficiency in road network performance refers to the effective management and optimization of transportation processes within a road network with the aim of enhancing the delivery of cargoes, resources, and services. It has been posited that some aspects of logistical efficiency consist of the reduction of operating costs and delivery times (Zawawi et al., 2017), the improvement of customer service, the creation of competitive advantages for cargoes (Ersoy & Tanyeri, 2021), and then the development of overall supply chain performance (Garza-Reyes et al., 2016). Besides, key elements of logistical efficiency also include improving freight movement via optimization of routes and average traffic speed, decrease in road congestion (W. K. Hsu et al., 2023), assurance of reliable deliveries, and provision of many parking spaces.

Second, convenience in road network performance is defined as the ease and comfort of travel for users within a road network. This concept focuses on the provision of convenient transportation options to enhance accessibility (Ersoy & Tanyeri, 2021), slow down travel and transfer times of vehicles (Nguyen et al., 2022), and as a result, improving the overall user experience (Nguyen et al., 2022). Key aspects of convenience include parking facilities (Garza-Reyes et al., 2016), information and communication (Özceylan et al., 2016), and safety and comfort (Zawawi et al., 2017). More specifically, Garza-Reyes et al. (2016) illustrated that convenient road networks with efficient parking management systems can help the means of transport reduce the waiting time, and access time into main roads. Furthermore, Özceylan et al. (2016) demonstrated that convenience for road users can be improved by providing real-time traffic updates, and road condition information. On top of that, the ability to access to accurate and up-to-date information enables travelers to make informed decisions and choose the most efficient routes (Esmailpour et al., 2020).

Third, Asakura and Kashiwadani (1991) can be seen as the first scholars to use the traffic fluctuation model (TFM) to investigate road network reliability, which is defined as the road network's ability to deal with travel demand in the context of disruptions and the possibility of overloading or wreckage of heavy freight for long distances. It is illustrated that the reliable road network focuses on minimizing variability and delays (Wang & Huang, 2016), and thus ensuring efficient and timely transportation for means of transport (Strano et al., 2017). According to Fusco et al. (2016), the reliable road network also reflects a high scope of flexibility and greater accessibility. In particular, the former represents the capacity of the road network system to accommodate changes in a variety of circumstances, including demand, behavior about route choice, infrastructure, costs, and rules, while still preserving a sufficient level of service.

Fourth, security and safety in road network performance are crucial aspects ensuring the well-being and protection of road users (Shanmugasundaram et al., 2019), vehicles (Fusco et al., 2016), infrastructure (Singh et al., 2018), etc. This definition also relates to the implementation of measures (i.e., guiding systems) and practices (i.e., road rescue services) to prevent accidents, minimize risks, and mitigate the impact of potential incidents within the road network. Kerimov et al. (2017) pointed out that road safety facilities (i.e., median barriers, delineation systems, electronic signals, etc.) can make up for the defects of the roadway environment, thereby contributing to safer travel. Thanks to that, road accidents can be reduced by up to 34% (Kim et al., 2015). Other factors, such as appropriate lane width, clear signage, proper lighting, and well-maintained surfaces, can enhance visibility for road drivers, and improving the risk of serious accidents.

Finally, connectivity is a critical factor in ensuring efficient and effective road transportation systems. Such a concept closely links to the accessibility (Zhang & Wang, 2016), directness, continuity (Papoutsis et al., 2018), redundancy (Fusco et al., 2016), and interconnectivity of roads within a network (Strano et al., 2017). Particularly, a well-connected road network is supposed to have many short links, numerous intersections, and minimal dead-ends (cul-de-sacs), thereby reducing travel distances and times and enabling seamless movement of passengers, cargoes, and services on roads. Also, there is a high level of consensus among researchers that road connectivity help nations promote economic activities, improve labor productivities (Wang & Huang, 2016), and boosting overall transportation efficiency.

3. Research methods

3.1. Assessment criteria and questionnaire design

This paper aimed to use the fuzzy AHP approach to estimate ACs' priority weight for the road transport network performance. Accordingly, the first was to create ACs' hierarchical structure for designing survey questionnaires (Dong et al., 2010; Taniguchi et al., 2016). Based on the aforementioned literature review, industrial experts' consultation, and the characteristics of road transportation, ACs' hierarchical structure, as shown in Table 1, was established, including five constructs in Layer 1 and twenty ACs in Layer 2. The next was to collect data on firms' judgments to verify the proposed research model. To achieve this, a 9-point Likert scale, originally developed by Saaty (1987), was employed to determine the importance and satisfaction levels of ACs from companies' perspective. The process for designing and validating such a scale was described as follows:

First, the preliminary questionnaire for logistical performance of the road transport network was composed of five constructs with a total of 20 ACs. A drafted version of the survey scale was created and tested by 07 industrial experts, including 03 from the cement and steel industries (i.e., VICEM and VNSTEEL), two from major transport companies (i.e., VIJAI and DHL), and two from the Vietnam Automobile Transportation Association (VATA). This pre-testing phase aimed to ensure that the statements in the questionnaire were comprehensible to respondents and no crucial questions were omitted. Secondly, based on pre-testing results, twelve ACs were revised to ensure that question items were concise and understandable. As a result, the draft scale was modified and was tested again with the same number of participants as in the prior phase. The final version of the questionnaire consisted of two main parts. In particular, Part 1 collected general information about the respondents, while Part 2 related to assessing the degree of importance and satisfaction regarding constructs and ACs.

Table 1: Hierarchical structure of assessment criteria

Constructs	*Assessment criteria*	*Explanation*	*References*
Logistical efficiency	Transport cost	The total cost involved in moving goods via road transport, including fuel, labor, tolls, maintenance, and other operational expenses	Zawawi et al. (2017), Kabak et al. (2018), Shepelev et al. (2020), Shepelev et al. (2020), Hsu et al. (2022), Garza-Reyes et al. (2016)
	Travel time	The average duration taken to transport goods from origin to destination.	
	Parking spaces	The availability of designated parking/loading/unloading zones for trucks and freight vehicles	
	Average traffic speed (Km/h)	The flow rate of vehicles on the road	
Convenience	Waiting time	The idle time experienced by transporters at terminals, intersections, or during transfers.	Özceylan et al. (2016), Esmailpour et al. (2020), Shanmugasundaram et al. (2019), Garza-Reyes et al. (2016), Özceylan et al. (2016), Zawawi et al. (2017)
	Access time	Time taken to reach the main road network or freight loading zones from origin/destination points	
	Transfer wait	Time lost during modal transfers (e.g., warehouse to truck)	
	The ability to transport at the short and long distances	The adaptability of the transport system for varying haul lengths	
Reliability	The road network's capability to	The system's resilience to incidents like accidents,	Asakura and Kashiwadani (1991), Wang and Huang

Constructs	*Assessment criteria*	*Explanation*	*References*
	cope with travel demand in case of disruptions	weather, or infrastructure failure	(2016), Strano et al. (2017), Fusco et al. (2016), Shepelev et al. (2020), Hsu et al. (2022), Özceylan et al. (2016), Zawawi et al. (2017)
	The possibility of overloading or wreckage of heavy freight for long distances	Structural strength and load-bearing capacity of roads to prevent breakdowns and delays	
	High scope of flexibility	The ability to reroute or adapt delivery schedules based on changing conditions	
	Greater accessibility	Ease of reaching various urban and rural zones via road transport	
Security and Safety	Road rescue services	Availability and responsiveness of emergency and breakdown assistance services	Kerimov et al. (2017), Kim et al. (2015), Fusco et al. (2016), Papoutsis et al. (2018), Singh et al. (2018), Strano et al. (2017), Wang and Huang (2016)
	Traffic accidents	Frequency and severity of accidents on specific road corridors	
	Safety facilities	Includes lighting, signage, barriers, and emergency call boxes	
	Suitability of guiding systems	ffectiveness of navigation aids, traffic information systems, and route planning tools in assisting drivers	
Connectivity	The number of nodes (vertexes)	Intersections, terminals, or access points in the transport network	Zhang and Wang (2016), Papoutsis et al. (2018), Fusco et al. (2016), Strano et al. (2017), Asakura and Kashiwadani (1991), Wang and Huang (2016)
	The number of edges (links)	The actual road segments connecting nodes	
	Personalised services	Availability of custom transport solutions, such as real-time tracking, adaptive routing, or customer-focused logistics services	

Constructs	*Assessment criteria*	*Explanation*	*References*
	The grid topology of the road system.	The layout structure of the network (e.g., grid, radial), which affects efficiency, coverage, and flow distribution	

Source: Reviewed from prior literature

3.2. Research sample

As mentioned above, the current article used the MK-VN case, as an empirical case, to verify the proposed research model. In doing so, the research directly interviewed 68 industrial experts working at 50 major companies in the Mekong Delta of Vietnam by designing nine-point questionnaires. Besides, interviewed participants must meet two criteria: (1) Being executive positions, (2) having at least 6 years of working experience in road transportation.

More crucially, because of using fuzzy AHP to calculate ACs' weight, respondents' judgment required a certain level of matrix consistency, which could be gauged by employing the consistency ratio (CR), as follows:

$$CR(n) = \frac{\left(L_{max} - n\right) / (n-1)}{MRCI(n)} \tag{1}$$

Where:

$L_{\max}$: the biggest eigenvalue of the personal matrix (PM) constructed from the judgments of each expert.

n : the criteria in each PM.

MRCI: consistent indexes' average values gathered from a random simulation of PMs. Its values are shown in Table 2. Saaty (1980) admitted that $CR \leq 10\%$ is the acceptable range. By adopting the function "*eigen()*" in the RStudio, we could determine L_{max} for all PMs of the MK-VN case. As a result, only 60 out of 68 responses satisfy the CR < 10%. Further, 60 respondents' background is illustrated in Table 3.

Table 2: Mean random consistency index

n	3	4	5	6	7	8	9	10
MRCI (n)	0.525	0.882	1.115	1.252	1.341	1.404	1.452	1.484

Source: Hsu et. al., (2022)

Table 3: Respondents' background

Features		*Frequency*	*%*
Age in years	<35	5	8.33
	36 ~ 40	7	11.67

Features		*Frequency*	*%*
	41 ~ 45	12	20.00
	46 ~ 50	19	31.67
	51 ~ 55	4	6.67
	56 ~ 60	6	10.00
	>60	7	11.67
Gender	Male	47	78.33
	Female	13	21.67
Experience in years	6 ~ 10	8	13.33
	11 ~ 15	11	18.33
	16 ~ 20	18	30.00
	21 ~ 25	13	21.67
	>25	10	16.67
Education	Ph.D.	3	5.00
	Master	22	36.67
	Barchelor	27	45.00
	Three ~ year college	5	8.33
	Vocational school	3	5.00
Position	President/Vice-president	7	11.67
	CEO/Vice-CEO	9	15.00
	General director/Deputy general director	5	8.33
	Chairman	13	21.67
	Vice - Chairman	21	35.00
	Senior staff	5	8.33
Business types	Private enterprises	7	11.67
	Limited liability companies	17	28.33
	Joint-stock companies	30	50.00
	Parnership	4	6.67
	State – owned enterprise	2	3.33

Source: Calculated by authors

3.3. Fuzzy AHP

The article takes ACs' importance measures under the LE dimension to demonstrate how to adopt a fuzzy AHP approach. As seen in Table 1, ACs under the LE construct embrace LE1, LE2, LE3, and LE4. The process to adopt the fuzzy AHP approach is detailed as follows:

(a) Defining the fuzzy positive reciprocal matrix (FPRM)

Let $E=(1,2,\ldots,k,\ldots,h)$ be the number of experts in the surveyed data. As noted earlier, each expert's rating results in one PM. Consequently, we have a total of *h* PMs from *h* respondents. Then, such *h* PMs can be combined to form a FPRM using Formula (2):

$$[l_{ij}, m_{ij}, u_{ij}] = \left[\min_{1\le k\le h}\left(a_{ij}^{(k)}\right), \left(\prod_{k=1}^{h} a_{ij}^{(k)}\right)^{1/h}, \max_{1\le k\le h}\left(a_{ij}^{(k)}\right)\right] \qquad (2)$$

Where a_{ij}^{k}, $i, j = 1, 2, \ldots, n$ and $k = 1, 2, \ldots, h$ be the importance level assigned to any two ACs i and j by the k^{th} expert. Based on Equation (2), we have the FPRM of the LE construct as follows:

$$\widetilde{A}_{LE} = \begin{bmatrix} (1.000\ \ 1.000\ \ 1.000) & (0.111\ \ 0.959\ \ 7.000) & (0.143\ \ 1.248\ \ 7.000) & (0.111\ \ 1.544\ \ 9.000) \\ (0.143\ \ 1.043\ \ 9.000) & (1.000\ \ 1.000\ \ 1.000) & (0.200\ \ 1.685\ \ 9.000) & (0.143\ \ 1.626\ \ 9.000) \\ (0.143\ \ 0.801\ \ 7.000) & (0.111\ \ 0.594\ \ 5.000) & (1.000\ \ 1.000\ \ 1.000) & (0.111\ \ 1.337\ \ 9.000) \\ (0.111\ \ 0.648\ \ 9.000) & (0.111\ \ 0.615\ \ 7.000) & (0.111\ \ 0.748\ \ 9.000) & (1.000\ \ 1.000\ \ 1.000) \end{bmatrix}$$

(b) Consistency check for FPRM

Wang and Lin (2017) argued that the consistent level of FPRMs might be tested by the geometric consistency index (GCI). Let $\widetilde{A} = (\widetilde{a}_{ij}) = \left(a_{ij}^{L}, a_{ij}^{M}, a_{ij}^{U}\right)_{n\times n}$ be FPRMs, whose GCI is figured out as:

$$GCI(\widetilde{A}) = \max\left\{\frac{2}{(n-1)(n-2)}\sum_{i<j}\left(\ln a_{ij}^{M} - \frac{1}{n}\sum_{k=1}^{n}\ln a_{ik}^{M} + \ln a_{kj}^{M}\right)^{2}; \right.$$
$$\left. \frac{1}{2(n-1)(n-2)}\sum_{i<j}\left[\ln a_{ij}^{L} + \log a_{ij}^{U} - \frac{1}{n}\sum_{k=1}^{n}\left(\ln a_{ik}^{L} + \ln a_{ik}^{U} + \ln a_{kj}^{L} + \ln a_{kj}^{U}\right)\right]^{2}\right\} \qquad (3)$$

Back to $\widetilde{A}_{LE}$, its GCI is calculated: $GCI\left(\widetilde{A}_{LE}\right) = \max\{0.0235;\ 0.0043\} = 0.0235$. Evidently $\widetilde{A}_{LE}$ is significantly consistent. In the same way, Table 4 shows consistency test results of the MK-VN case.

Table 4: Consistency test

	Layers	GCI	Conclusion
Expected importance	Layer 1	0.0322	Consistent
	Layer 2: LE	0.0235	Consistent
	Layer 2: CV	0.0122	Consistent
	Layer 2: RL	0.0170	Consistent
	Layer 2: SS	0.0135	Consistent
	Layer 2: CN	0.0322	Consistent
Perceived Satisfaction	Layer 1	0.0284	Consistent
	Layer 2: LE	0.0296	Consistent
	Layer 2: CV	0.0208	Consistent
	Layer 2: RL	0.0148	Consistent
	Layer 2: SS	0.0938	Consistent
	Layer 2: CN	0.0303	Consistent

Source: Calculated by authors

(c) The fuzzy weight of ACs

According to Dong et al. (2010), the fuzzy geometrical properties of the pairs of FPRMs are defined as follows:

$$\tilde{t}_i=\left(\prod_{j=1}^{n}\tilde{a}_{ij}\right)^{\frac{1}{n}}=\left[\left(\prod_{j=1}^{n}l_{ij}\right)^{\frac{1}{n}},\ \left(\prod_{j=1}^{n}m_{ij}\right)^{\frac{1}{n}},\ \left(\prod_{j=1}^{n}u_{ij}\right)^{\frac{1}{n}}\right],\ i=1,2,\ldots,n. \qquad (4)$$

$$\Rightarrow\ \sum_{i=1}^{n}\tilde{t}_i=\sum_{i=1}^{n}\left(\prod_{j=1}^{n}\tilde{a}_{ij}\right)^{\frac{1}{n}}=\left[\sum_{i=1}^{n}\left(\prod_{j=1}^{n}l_{ij}\right)^{\frac{1}{n}},\ \sum_{i=1}^{n}\left(\prod_{j=1}^{n}m_{ij}\right)^{\frac{1}{n}},\ \sum_{i=1}^{n}\left(\prod_{j=1}^{n}u_{ij}\right)^{\frac{1}{n}}\right],\ i=1,2,. \qquad (5)$$

Thanks to Equations (4) and (5), the fuzzy weight of $AC_i\ (i=1,2,\ldots,n)$ can then be obtained as:

$$\tilde{w}_i=\left[\frac{\left(\prod_{j=1}^{n}l_{ij}\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n}u_{ij}\right)^{1/n}},\ \frac{\left(\prod_{j=1}^{n}m_{ij}\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n}m_{ij}\right)^{1/n}},\ \frac{\left(\prod_{j=1}^{n}u_{ij}\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n}l_{ij}\right)^{1/n}}\right];\ i=1,2,\ldots,n \qquad (6)$$

Return to the LE construct, based on Equations (4), (5), and (6), the fuzzy weights for the *i*th AC (*i* =1,2,…,4) are as:

$$\begin{bmatrix}\tilde{w}_1\\ \tilde{w}_2\\ \tilde{w}_3\\ \tilde{w}_4\end{bmatrix}=\begin{bmatrix}0.0109 & 0.2845 & 5.5393\\ 0.0134 & 0.3173 & 6.0769\\ 0.0109 & 0.2179 & 4.9269\\ 0.0102 & 0.1803 & 5.7058\end{bmatrix}$$

(d) The local weight of ACs

Since the ACs' weight as computed in the last section are fuzzy numbers $(\tilde{w})$. One may compute the grading average integrating representations (GAIRs) of the matrix $\tilde{w}$ to determine the local weight of ACs:

$$w_i=\frac{l_i^w+4\times\left(m_i^w\right)+u_i^w}{6},\ i=1,2,\ldots,n \qquad (7)$$

Normalize $w_i\ (i=1,2,\ldots,n)$, the crisp weight of the i^{th} AC is obtained as:

$$\omega_i=\frac{w_i}{\sum_{i=1}^{n}w_i},\ i=1,2,\ldots,n \qquad (8)$$

By means of Equations (7) and (8), the local weights of the LE construct (i.e., LE1, LE2, LE3, and LE4) are attained: $w^{LE}=\left[1.0847,\ 1.2266,\ 0.9638,\ 1.0730\right]$, and then $\omega^{LE}=\left[0.2492,\ 0.2818,\ 0.2225,\ 0.2465\right]$. Similarly, the local weights for importance measures (IWs) and satisfaction measures (SWs) for the other constructs are computed as seen in Table 5.

Table 5: Priority weights for assessment criteria

Layer 1: Constructs	*Global weights in Layer 1*		*Layer 2: Criteria*	*Local weights in Layer 2*		*Global weights in Layer 2*	
	IWs	*SWs*		*IWs*	*SWs*	*IWs*	*SWs*
Logistical efficiency (LE)	21.02	18.59	LE1	24.92	25.68	5.24	4.77
			LE2	28.18	26.02	5.92	4.84
			LE3	22.25	24.56	4.68	4.57
			LE4	24.65	23.73	5.18	4.41
Convenience (CV)	20.94	21.05	CV1	25.61	26.12	5.36	5.50
			CV2	25.43	26.33	5.32	5.54
			CV3	24.23	24.28	5.07	5.11
			CV4	24.74	23.28	5.18	4.90
Reliability (RL)	18.50	20.09	RL1	22.35	27.11	4.13	5.45
			RL2	24.93	23.86	4.61	4.79
			RL3	25.82	25.62	4.78	5.15
			RL4	26.90	23.41	4.98	4.70
Security and Safety (SS)	21.58	19.95	SS1	24.51	21.91	5.29	4.37
			SS2	26.85	21.32	5.79	4.25
			SS3	26.08	21.32	5.63	4.25
			SS4	22.56	35.45	4.87	7.07
Connectivity (CN)	17.96	20.33	CN1	23.95	24.19	4.30	4.92
			CN2	23.25	22.99	4.18	4.67
			CN3	27.59	27.40	4.96	5.57
			CN4	25.21	25.41	4.53	5.16

Source: Calculated by authors

(e) The global weight of ACs

The ACs' global weight is figured out by multiplying the constructs' global weight (in Layer 1) and the ACs' local weight (in Layer 2). Consequently, ACs' global weight for importance measures (IWs) and satisfaction measures (SWs) are obtained and shown in the two last columns of Table 5.

3.4. The IPA model

By means of IWs and SWs in the two last columns of Table 5, it is figured out that IWs and SWs averaged 5% each. These average values divide the IPA grid into four quadrants, as seen in Figure 1. More particularly, Quadrant I with high-importance and high-performance comprises 3 ACs (i.e., CV1, CV2, and CV3). In theory, ACs in this quadrant can serve as benchmarks or reference points for areas needing improvement. Accordingly, policies for these ACs are "keep up the good work". Next, Quadrant II, characterized by high-importance and low-satisfaction includes 7 ACs (i.e., CV4, LE1, LE2, LE4, SS1, SS2, and SS3). These attributes require improvement and should be a top priority for resource allocation. Thus, policies for these ACs should be "concentrate here". Quadrant III with low-importance and low-satisfaction embraces 5 ACs (i.e., CN1, CN2, RL2, RL3, and RL4).

These attributes may not be a high priority for improvement. Therefore, policies for them should be "low priority". Finally, Quadrant IV with low-importance and high-performance consists of 5 ACs (i.e., RL1, CN4, SS4, CN3, and RL3). Therefore, policies for them should be "possible overkill".

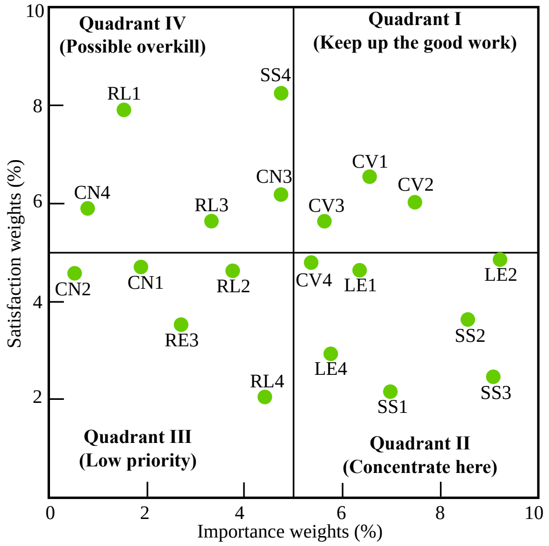

Figure 1: The IPA model for the MK-VN case

Source: drawn by authors

4. Results and discussions

4.1. Importance magnitude of constructs and ACs

As shown in the second field of Table 5, the relative importance degree of constructs for the assessment of logistical performance for the road transport network is ranked as security and safety, logistical efficiency, convenience, reliability, and connectivity, respectively. More specifically, security and safety are viewed as the most cruial by companies, with a priority importance weight of 21.58%. Evidently, security and safety are two critical aspects of the road transport network, whose interrelationship between them ensures the well-being of passengers (Singh et al., 2018), cargoes (Papoutsis et al., 2018), and the overall functioning of the transportation system (Fusco et al., 2016). Strano et al. (2017) demonstrated that road safety primarily helps prevent possible accidents and minimize the risk of injury or death on roadways, while road security focuses on protecting road infrastructure, vehicles, and the transportation system from various threats and risks.

The second important construct is logistical efficiency, with its priority importance weight of 21.02%. It is argued that logistical efficiency in road transport refers to the ability to move cargoes and passengers from one location to another (Fazili et al., 2017). Accordingly, logistically efficient road network can help firms maximize the use of resources (Shepelev et al., 2020), minimize operating costs (Papoutsis et al., 2018), and ensure timely and reliable deliveries (Strano et al., 2017).

On top of that, as displayed in the second-last column of Table 5, the top five ACs with the highest importance weight in Layer 2 consist of travel time (5.92%), traffic accidents (5.79%), safety facilities (5.63%), waiting time (5.36%), and access time (5.32%). This empirical result can provide useful information for the government authorities of Vietnam in making improvement policies for logistical performance of the road transport network.

4.2. The improvement policies for ACs

According to results from the IPA model in Figure 1, seven ACs in Quadrant II (i.e., *transport cost*, *travel time*, *traffic accidents*, *average traffic speed*, *the ability to transport at short and long distances*, *safety facilities*, and *road rescue services*) should be the top priority for improvement policies of the government authorities. In addition, limited resources allocating ACs in Quadrant IV should be deployed elsewhere, especially ACs in Quadrant II. From such empirical results, this study interviewed face-to-face with some industrial experts working at major companies, and some high-ranking officials of the government authorities. As a result, some recommendations for enhancing logistical performance of the road transport network were suggested, as follow:

First of all, interviewed experts reached a high agreement that investing in road infrastructure is a number-one priority to improve logistical performance for the road transport network. Further, governments can allocate funds for the construction, maintenance, and expansion of road networks. They also explained that by doing so, travel time and transport costs can be reduced appreciably, and, in turn, traffic accidents and average traffic speed may be improved. Singh et al. (2018) also have a similar suggestion.

Secondly, to guarantee the ability to transport at short and long distances, interviewed experts suggested promoting intermodal transportation by integrating road networks with other modes, such as railways, ports, and airports. Besides, another suggested policy is to develop multimodal transportation hubs, for instance, logistics parks and interchanges to efficiently transfer goods and passengers between different modes of transportation. Such recommendations are in agreement with those of Strano et al. (2017).

Last but not least, ensuring safety facilities and road rescue services in road transport is essential for guarding against road accidents and giving timely assistance in case of emergencies. Therefore, interviewed experts suggested the establishment of rest areas and service stations along highways and major roads where drivers can take breaks, rest, and access basic amenities (i.e., restrooms and food). In reality, this suggestion has been implemented in some provinces (i.e., Can Tho, Dong Thap, An Giang, and Tien Giang) since 2021 according to the Highway Development Project in the Mekong Delta during 2021-2026.

5. Conclusion

The current paper aims at assessing logistical performance for the road transport network by the IPA model based on Fuzzy AHP. For the empirical case, the current article surveyed major companies in the Mekong Delta of Vietnam to validate the suggested proposed framework. Some main contributions of this research are summarized, as follows:

First, from an extensive literature review, industrial experts' consultation, and the characteristics of road transportation, this paper argues that assessing logistical performance for the road transport network involves five constructs with 20 ACs. By adopting fuzzy AHP, it is found that security and safety (21.58%) is the most crucial construct from the enterprises' perspective, followed by logistical efficiency (21.02%), convenience (20.94%), reliability (18.50%), connectivity (17.96%). Besides, the top five ACs with the highest importance weight in Layer 2 embrace travel time (5.92%), traffic accidents (5.79%), safety facilities (5.63%), waiting time (5.36%), and access time (5.32%). This empirical result can provide useful information for the government authorities of Vietnam in making improvement policies for logistical performance for the road transport network.

Secondly, the IPA model figures out four Quadrants for policy planning. In particular, seven ACs should be the top priority for improvement policies of the government authorities, including *transport cost, travel time, traffic accidents, average traffic speed, the ability to transport at short and long distances, safety facilities,* and *road rescue services*. More importantly, industrial experts also suggest some strategies to improve such 7 ACs, such as (1) investing in road infrastructure to improve logistical performance for the road transport network, (2) promoting intermodal transportation by integrating road networks with other modes to provide seamless transportation solutions for long-distance cargo movement, (3) building and maintaining rest areas and service stations along highways and major roads.

Thirdly, the combination of IPA and fuzzy AHP provides a methodological reference for relevant literature. This approach can be extended to investigate logistical performance for other transport systems, such as railways, airways, waterways, etc. Most critically, the suggested research model may be applicable to some countries, for instance, the Philippines, Cambodia, etc., which have as similar conditions as Vietnam.

At last, limitations are as follows. First, the adoption of fuzzy AHP requires the assumption about the independence of constructs and ACs in the evaluation structure. Nonetheless, such an assumption is not verified in this paper. Accordingly, it is recommended that further studies should innovate the traditional fuzzy AHP to ensure independence of evaluated criteria, such as using the influence matrix (Hsu et al., 2022). Secondly, it has been illustrated that assessing logistical performance for the road transport network involves many stakeholders, such as companies, local residents, and government officials. Yet, the present article merely investigates companies to verify the proposed research model. It is highly advised that future studies should include other stakeholders, for example, local residents and government officials, in the surveyed sample for better policies. Third, it is noted that while the combination of IPA and Fuzzy AHP provides flexible framework for evaluating logistics performance under uncertainty, it is partially reliant on expert judgment, which may introduce subjectivity despite the use of fuzzy logic to mitigate bias. Thus, this limitation leave room for future studies.

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