Assessing the Factors Influencing Internet of Things Adoption in the Freight Transport and Logistics Industry

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Abstract

The Internet of Things (IoT) is one of the primary technologies of Industry 4.0. It is widely regarded as an essential infrastructure for enhancing the transparency of business processes and the accuracy of business decisions. Despite the popularity and applicability of IoT across industries, there is little understanding of IoT adoption factors in the Freight Transport and Logistics Industry (FTLI). This study investigates the factors for the adoption of IoT in the FTLI. The factors are identified and classified based on the Technology-Organization-Environmental framework and prioritized the factors using Fuzzy Analytic Network Process. The relative and dependency weights of each dimension and factor within each dimension have been determined, and it has been found that technology is the most prioritized dimension. Further, Competitive Advantage, Management Support, Security and Privacy, Technology Readiness and Capabilities, and Government Policy and Support are the most prioritized five factors for IoT adoption in FTLI. These findings will help government agencies and policymakers to develop freight transport strategies, such as Model share for freight transport and National Rail Plans. The study also assists transport managers in devising a plan to embrace Industry 4.0 and its requirements in the FTLI.

Keywords
Internet of Things (IoT); Freight Transport and Logistics Industry (FTLI); TOE framework; Fuzzy Analytic Network Process (FANP); and MCDM Method

1. Introduction
Globalization has created a massive demand for international trade. Freight transport has emerged as one of the essential areas that can contribute to expanding international business through the most efficient movement and delivery. Along with this, freight transport generates unwanted externalities, such as congestion, pollution, accident, and infrastructure deterioration which hinder sustainability. These externalities have become critical as globalized exports increased by 13.8% (UNCTAD 2022). These vulnerability problems of freight transport can be assessed and regulated through the adoption of Industry 4.0, which emphasizes end-to-end digitization (Thoben et al. 2017) and is associated with many technologies, like the Internet of Things (IoT), Blockchain, and Cloud computing (Falwadiya and Dhingra 2022).

IoT implementation is the initial phase of Industry 4.0, as it has the facility to convert and integrate physical devices into digital networks (Čolaković and Hadžialić 2018). According to Ben-Daya et al. (2019), "IoT is a network of physical objects that are digitally connected to sensor, monitor, and interact within a company and between the company and enabling agility, visibility, tracking, and information sharing to facilitate timely planning, control, and coordination of the processes" (p. 4721). IoT adoption gathers real-time data and arrives at suitable decisions from that information. It enriches the innovation in the firm and optimizes the utilization of resources, improves security and privacy, better realization for stakeholders, and makes it more sustainable (Kamble et al. 2019). The adoption of IoT in the freight transport and logistics industry (FTLI) has many advantages, such as improving connectivity among stakeholders, tracking and monitoring routes and vehicles, enhancing security and safety, improve operator performance and last-mile delivery (Ahmed et al. 2021). Therefore, IoT adoption is crucial in strengthening the business's performance and growth, including FTLI.

Regardless of the benefits explained above on implementing IoT across industries, the extant literature has found a handful of research on IoT adoption in the FTLI domain. These studies focused on the relationship between factors in the conventual supply chain (Tu 2018) and the food supply chain (Kamble et al. 2019). Rey et al. (2021) studied the transport and logistics industry empirically. However, to my knowledge, the literature contains no evidence of IoT adoption in FTLI. This study addresses this research gap by identifying the IoT adoption factors of the FTLI and prioritizing these factors by estimating the weight of the factors. These factor weights assist the management of FTLI in understanding the significance and strategies for adopting IoT in their organizations. The specific research questions for the study are: Which factors encourage embracing IoT in Freight Transport and Logistics Industry? How are these factors prioritized in the process of adoption?

1.1 Objectives

This study focuses on the following research objectives considering the knowledge mentioned above gap:

- **RO1:** Identify the potential factors impacting IoT adoption in Freight Transport and Logistics Industry (FTLI) and categorize them according to the Technology-Organization-Environmental (TOE) framework.
- **RO2:** Evaluate the relative weight of dimensions and factors pertaining to prioritizing the suitability for the adoption of IoT in FTLI.

2. Literature Review

This section briefly explored the literature on IoT adoption for the freight transport and logistics industries. Additionally, identify the factors impacting IoT adoption in FTLI and organize them based on three different contexts: Technology, Organization, and Environmental.

2.1 IoT in the Freight transport and logistics industry (FTLI)

IoT is a growing system integrating physical devices into digital network systems to track real-time operations. This network regulates through the connection of the internet. IoT application significantly impacts attaining the objectives of Industry 4.0 (Ben-Daya et al. 2019; Hsu and Yeh 2017; Tu 2018). The IoT-enabled system emphasizes the bottleneck section of the system and reduces risks that arise due to uncertainty, increasing flexibility, transparency, and visibility through controlled decisions (Ben-Daya et al. 2019). Literature explored the adoption of IoT in various industries, including manufacturing (Cui et al. 2021), healthcare (Belfiore et al. 2022), and agriculture (Pillai and Sivathanu 2020).

A limited number of studies scrutinized the impact of IoT adoption on the transport and logistics industries, including some supply chains such as intermodal, retail, and food (Hsu and Yeh 2017; Tu 2018; Kamble et al. 2019; Rey et al. 2021). The consequences of these adoptions in supply chains have shown numerous benefits, such as monitoring transit operations through tracking and tracing, improving security and privacy, reduce or removing human interactions and risks. The findings also identified the bottleneck sections through continuous information from the network and tried to reduce or eliminate the limitations(Macaulay et al. 2015; Yang et al. 2018).

Despite the satisfactory evidence of IoT adoption in various fields and the ability to decrease logistics costs, FTLI has less focused on this aspect. Literature also explored that technology adoption, like IoT, depends on multiple levels of decision-makers and the number of associated factors (Hsu and Yeh 2017; Tu 2018; Kamble et al. 2019). The decision-makers belong to different levels of management, from the head of the department to the CEO of the company. The factors that help in decisions are technological, organizational, and external environmental. Some factors are controllable, and some are uncontrolled and unavoidable for the company. Therefore, multi-criteria decision-making (MCDM) models can help understand and investigate the factors influencing IoT addition in FTLI.

2.1 IoT adoption factors in the TOE framework

The IoT implementation factors impacting FTLI are identified from the literature and verified by the experts. These factors are classified based on TOE theoretical framework. This framework assists in exploring the implementation of emerging technology, like IoT, and demonstrates the characteristics of factors in three different contexts: Technology, Organization, and Environment (Tornatzky, L. and Fleischer 1990). In a technological context, the focus is on the technical feature of IoT useful for FTLI, such as perceived benefits from IoT, characteristics of IoT, and availability and accessibility of the infrastructure. In an organizational context, the focus is on the scale of the firm, communication process, connecting network and structure, etc. In an environmental context, the focus is on the factors external to the firm, such as government regulation and globalization. The TOE framework is often used in emerging technology adoption studies. Table 1 shows the IoT adoption factors impacting FTLI in technology, organization, and external environmental contexts.

Table 1. Internet of Things adoption factors in the freight transport and logistics industry

Dimensions	Factors	Acronym	References
Technology	Competitive advantage	COA	(Cui et al. 2021; De Prieelle et al. 2022; Demirkesen and Tezel 2022; El Baz et al. 2022; Hsu and Yeh 2017; Kamble et al. 2018, 2019; Karuppiah et al. 2022; Khin ans Kee 2022; Ly et al. 2018; Masood and Sonntag 2020; Parhi et al. 2022; Pasi et al. 2022; Rey et al. 2021; Srivastava et al. 2022; Vimal et al. 2022)
	Security and privacy	SAP	
	Technical readiness and capability	TRC	
	Ease of use	EOU	
	Compatibility	COM	
	Accuracy and flexibility	AAF	
Organization	Management support	MGS	(Cui et al. 2021; De Prieelle et al. 2022; Demirkesen and Tezel 2022; El Baz et al. 2022; Hsu and Yeh 2017; Jayashree et al. 2022; Kamble et al. 2018, 2019; Karuppiah et al. 2022; Khin and Kee 2022; Parhi et al. 2022; Pasi et al. 2022; Srivastava et al. 2022)
	Investment cost	IVC	
	Infrastructure	INF	
	Employee capability	EMC	
	Training and education of the employee	TEE	
	Organizational background	ORB	
Environmental	Government policy and support	GPS	(Cui et al. 2021; Demirkesen and Tezel 2022; El Baz et al. 2022; Hsu and Yeh 2017; Jayashree et al. 2022; Kamble et al. 2018; Karuppiah et al. 2022; Khin and Kee 2022; Parhi et al. 2022; Pasi et al. 2022; Srivastava et al. 2022; Vimal et al. 2022)
	Globalization	GLO	
	Sustainability	SUS	
	Industry competitive pressure	ICP	
	Stakeholders' relationship	STR	
	Uncertainty and risks	UAR	

3. Research Methodology

This section explains the outline of the research methodology used in the study. This study uses a Fuzzy Analytic Network Process (FANP) method and a TOE theoretical framework to analyze the IoT adoption factors in the FTLI, as shown in Figure 1. The ANP is a multi-criteria decision-making (MCDM) method used to establish a network structure of factors, dimensions, and goal of the analysis and evaluate the weight of the factors and dimensions. This method is the advanced form of the Analytic Hierarchy Process (AHP) method developed by Saaty (1980). ANP has been effectively implemented in various contexts of supply chains and logistics domains (Shardeo et al. 2020). ANP needs a pairwise comparison of factors and dimensions by the experts. Sometimes, comparisons by experts' judgments create some bias in the decisions. This shortcoming can be easily overcome by integrating fuzzy logic in the ANP (Shardeo et al. 2020). This method uses triangular fuzzy numbers (TFN) for collecting the relevant data in the form of a pairwise comparison matrix using the linguistic scale shown in Table 2. The steps to determine the weight of the factors using FANP are following:

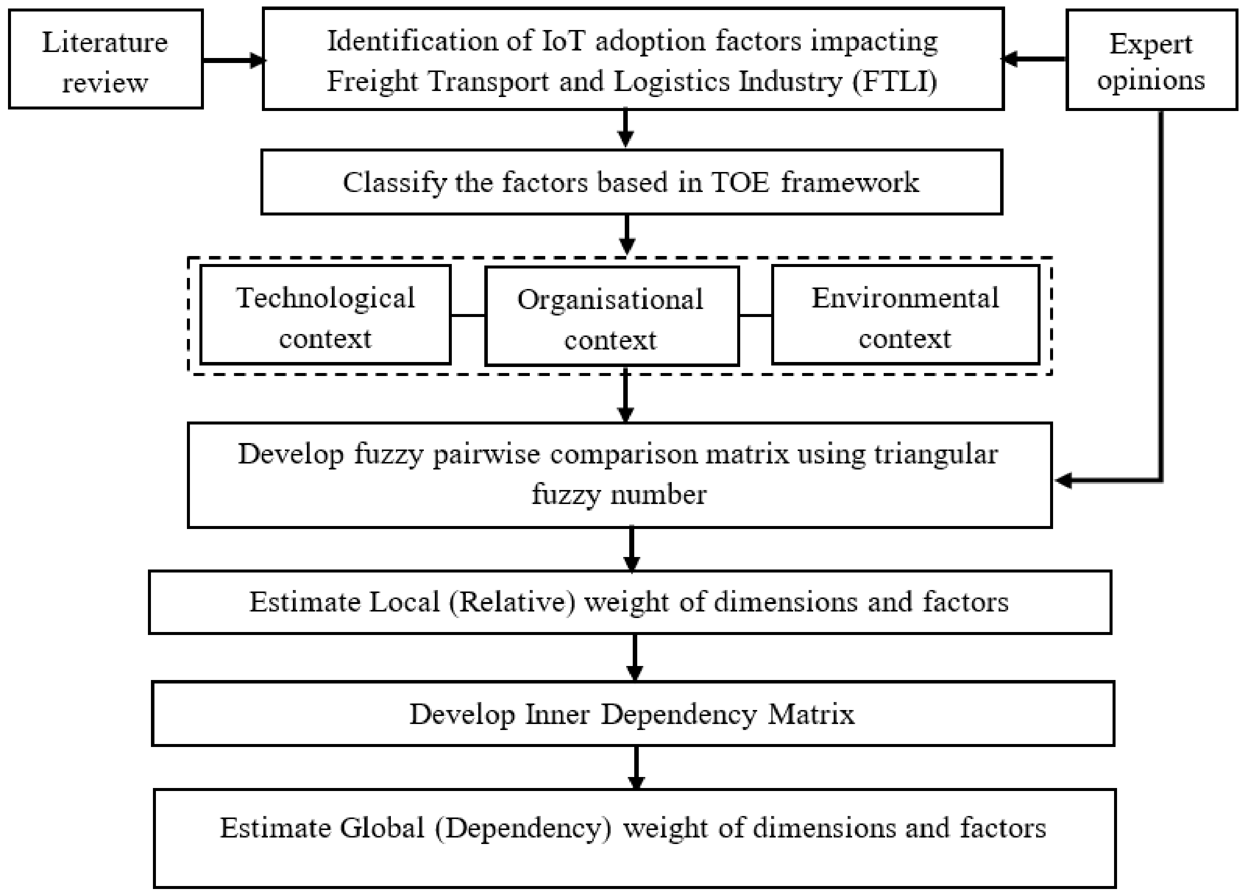

Figure 1. A research framework for IoT adoption in FTLI

Table 2. Linguistic scale of Triangular Fuzzy numbers

Linguistic attributes	**Importance intensity**	**Fuzzy numbers**	**Triangular Fuzzy scale**
Equal importance	1	$\tilde{1}$	(1,1,1)
Moderate importance	3	$\tilde{3}$	(2,3,4)
Strong importance	5	$\tilde{5}$	(4,5,6)
Very strong importance	7	$\tilde{7}$	(6,7,8)
Extreme importance	9	$\tilde{9}$	(9,9,9)

3.1 Relative (Local) weights

The first step is to get the experts' opinions on the pairwise comparison matrix based on important intensity and convert it to triangular fuzzy numbers, as shown in Table 2. The pairwise comparison matrix (C) is developed for dimensions and factors by each expert using Equation 1, and aggregate the matrix using Equation 2. The fuzzy weight ($\tilde{w}_j$) is calculated according to Equation 3 using the fuzzy geometric mean method (Buckley 1985). This fuzzy weight is converted to the final fuzzy crisp weight (w_j) using center of area defuzzification method according to Equation 4. Where, j is IoT adoption factors, and m is triangular fuzzy numbers in fuzzy scale (l, m, u), as shown in Table 2.

$$C = \begin{bmatrix} 1 & \tilde{c}_{12} & \cdots & \tilde{c}_{1n} \\ \tilde{c}_{21} & 1 & \cdots & \tilde{c}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{c}_{n1} & \tilde{c}_{n2} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} 1 & \tilde{c}_{12} & \cdots & \tilde{c}_{1n} \\ \frac{1}{\tilde{c}_{12}} & 1 & \cdots & \tilde{c}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{\tilde{c}_{1n}} & \frac{1}{\tilde{c}_{2n}} & \cdots & 1 \end{bmatrix} \quad (1)$$

$$\tilde{c}_j = \left(\tilde{c}_{m1}{}^{1} * \ \tilde{c}_{m2}{}^{2} * \cdots * \ \tilde{c}_{mn}{}^{n}\right)^{\frac{1}{n}} \quad (2)$$

$$\tilde{w}_j = \tilde{c}_j * (\tilde{c}_1 + \ \tilde{c}_2 + \cdots + \ \tilde{c}_n)^{-1} \quad (3)$$

$$w_j = \frac{1}{3}\,(l + m + u) \quad (4)$$

3.2 Dependency (Global) weights

The Inner dependency matrix (M) of the dimensions is established by conducting a pairwise comparison of one dimension with respect to others according to Equation 5, where M is the inner dependency matrix and m_{ij} is the effect of i^{th}dimension over j^{th} dimension. Evaluating the interdependent weight vector according to Equation (6) and normalizing this vector according to Equation (7), where W_2 is the interdependent weight vector study, and W is the normalized interdependent weight vector.

$$M = \begin{bmatrix} 1 & m_{12} & m_{13} \cdots & m_{1n} \\ m_{21} & 1 & m_{23} & m_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ m_{n1} & m_{n2} & m_{n3} \cdots & 1 \end{bmatrix} \quad (5)$$

$$W_2 = M * W_1 = \ [w_1, w_2, \cdots, w_n] \quad (6)$$

$$W = \left[\frac{w_1}{\sum_{i=1}^{n} w_i}, \frac{w_2}{\sum_{i=1}^{n} w_i}, \cdots, \frac{w_n}{\sum_{i=1}^{n} w_i}\right] \quad (7)$$

The global weight of factors can calculate by multiplying dependency weights of dimensions (W) from Equation (7) and the corresponding local weight of factors (w_j) from Equation (4).

4. Data Collection

The present study used the Fuzzy Analytic Network Process (FANP)method to understand IoT's impact on the freight transport and logistics industry. This MCDM method required an expert survey for the data analysis. A total of 36 experts from 14 organizations with decent working experience contributed from all three modes of freight transportation. Table 3 demonstrates the demographic characteristics of the experts, such as education, professional experiences, designated posts in the organization, and features of the organization, such IoT implementation stage. Each organization was visited to reach the expert with sets of questionnaires and encouraged them to contribute through their judgments. The experts were also assured that the opinions given for this survey were confidential and used only for academic research.

Table 3. Demographic summary of the experts

Attribute		**Number of experts**	**% of the sample**
Number of organizations		14	-
Number of experts		36	-
Education	Bachelor's degree	16	44.44
	Master's degree	20	55.56
Experience (Years)	Less than 10	9	25
	Between 10 and 20	17	47.22
	More than 20	10	27.78
Designation	Executive	9	25
	Assistant Manager	5	18.89
	Senior Manager	10	27.78
	General Manager	12	33.33
Stage of IoT implementation	Not yet think	7	19.44
	Interested and explored	7	19.44
	Under implementation	17	47.23
	Implemented	5	13.89

5. Results and Discussion

This section demonstrates the findings of the results and critically discusses the interpretations. As discussed in the previous section, the questionnaires were filled for factors and dimensions in the form of pairwise comparisons by the experts, and these individual matrices were aggregated. Finally, the relative and dependency weight of dimensions and factors are determined.

5.1 Relative and dependency weight of dimensions

The relative and dependency weights of dimensions for IoT adoption in FTLI were assessed using the FANP method, as shown in Figure 2. It can observe that technology has been prioritized for adopting IoT in FTLI. It has given almost 55% and 43% of the weightage in relative and dependency weight, respectively. The technological dimension is crucial for IoT adoption as the factors associated with technology has extremely fundamental for innovation like IoT. It also showed that the findings are aligned with the requirement of Industry 4.0, and IoT is the first step toward achieving Industry 4.0. The organizational context is always an important aspect of adopting new technology, as this aspect is associated with managerial and related support for the adoption and adoption decision. This finding also shows the same for organizational context, giving almost one-third of the total weightage. The least important dimension in this scenario is the external environment which has approximately 20% of the weightage.

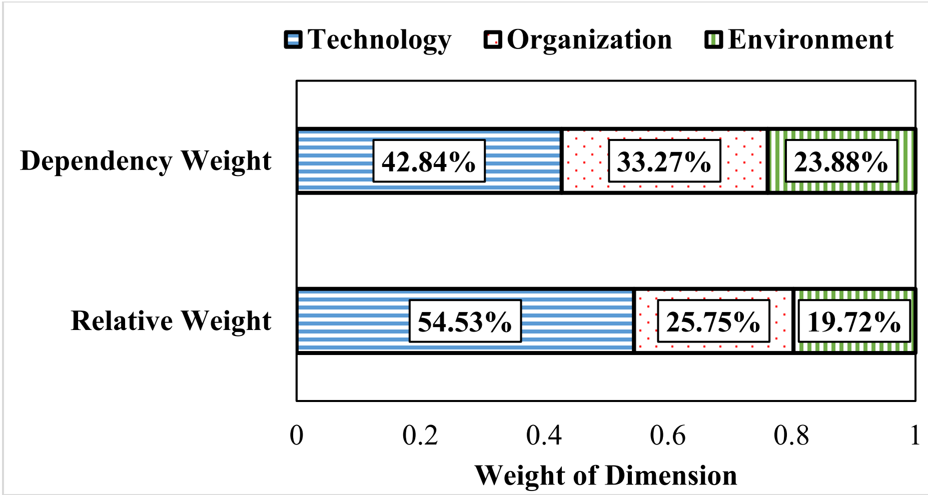

Figure 2. Comparison of the weight of IoT adoption dimensions for the FTLI

5.2 Relative and dependency weight of factors

The relative and dependency weights of IoT adoption factors in FTLI are shown in Figure 3. It can observe that Competitive Advantage, Management Support, and Government Policy and Support are the most weighted (relative) factors in technology, organization, and environmental dimensions, respectively. It can also observe that the five most global (dependency) weight factors are Competitive Advantage, Management Support, Security and Privacy, Technology Readiness and Capabilities, and Government Policy and Support. Most of these factors are from a technological dimension, including three technological, one organizational, and one environmental factor. Conversely, the five least global weight factors are Stakeholders' Relationship, Uncertainty and Risk, Organizational Background, Training and Education of Employees, and Industry Competitive Pressure. Most of these factors are from the environmental dimension, including three from the environment and two from the organization. Therefore, it can be clearly observed that FTLI has placed the most emphasis on technological factors and the least on external environmental factors in implementing IoT.

The technological factors are the base factors for the IoT and its characteristics, such as accuracy, security, privacy, flexibility, and compatibility. These factors assist the transporters to work with ease and achieve a competitive advantage. The environmental factors are uncontrolled factors for the transport sectors. These factors are imposed by society, such as stakeholder relationships and industry competitive pressure, or enforced by the institutions, such as sustainability and policy. Organizational factors are always given moderate importance as these factors are elementary (resource) factors for an organization, such as infrastructure, financial capital, and employees. The improvement of transport sectors is possible by optimum utilization of resources such as infrastructure and capital, unconditional support from top-level management, and effective contributions and performance from employees.

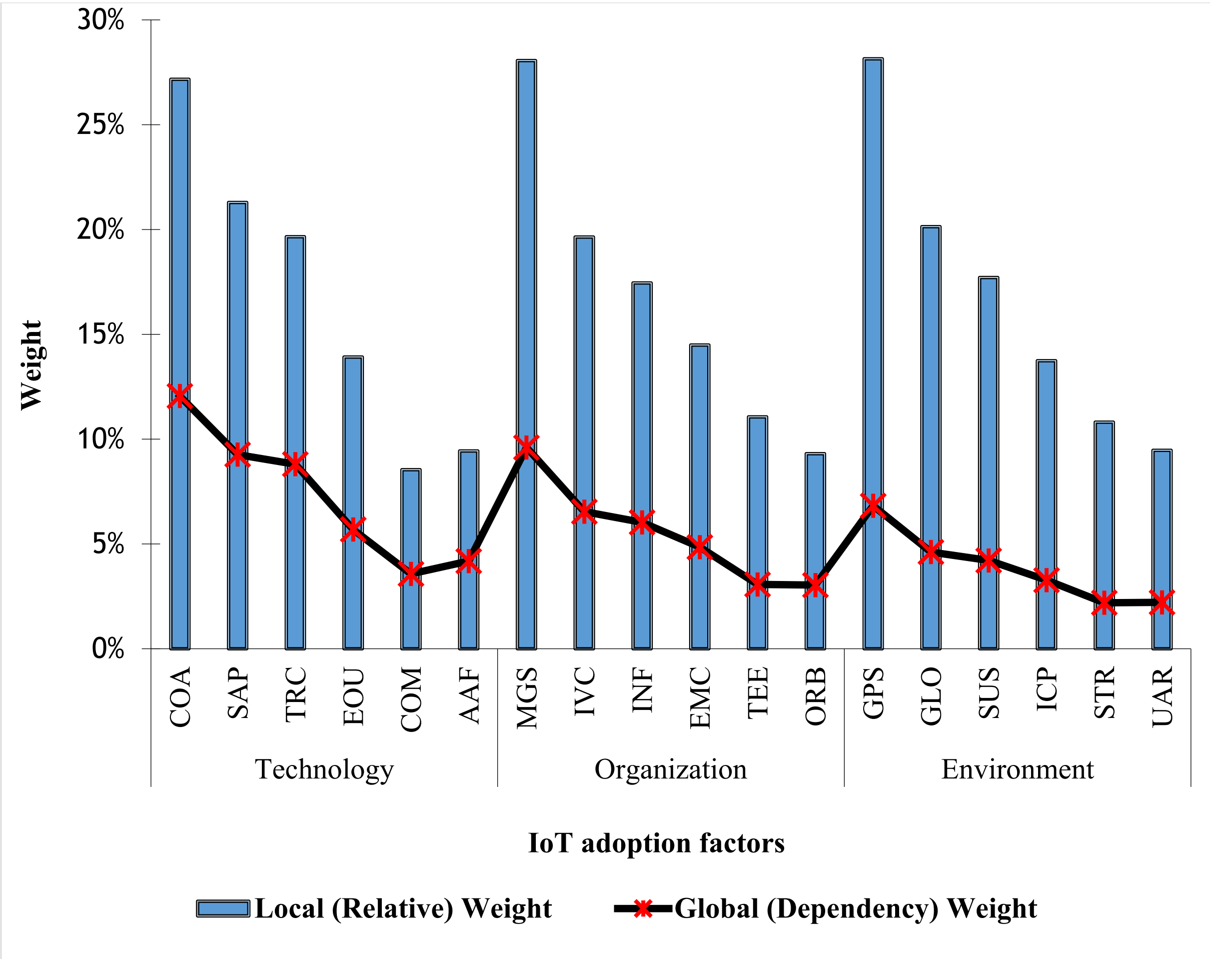

Figure 3. Local and global weight of IoT adoption factors for the FTLI

6. Theoretical Contributions and Managerial Implication

The current study contributes significantly to the technology adoption literature in FTLI. Firstly, the relevant IoT adoption factors are identified in the logistics domain to embrace Industry 4.0. Secondly, the identified factors are classified into three different contexts: technology, organization, and environmental. Thirdly, the relative and dependency weight of dimensions and factors are estimated to prioritize them during IoT adoption decisions and in the implementation process. The finding showed that the technological context is prioritized more for IoT adoption as most technological factors are extremely fundamental for IoT. In contrast, environmental context is the least prioritized as some environmental factors do not control transport companies, such as globalization, and some do not directly help financial performance, such as sustainability. Therefore, a nation must enforce some guidelines to maintain environmental requirements. These insights are new regarding IoT adoption in FTLI (Hsu and Yeh 2017; Tu 2018; Kamble et al. 2019; Rey et al. 2021).

Apart from the above theoretical contributions to the literature, the study also has implications for various stakeholders, especially government agencies, policymakers, and managers of FTLI. The managers plan their technology implementation strategies aligned with the requirements of Industry 4.0, which can help develop diverse capabilities and achieve competitive advantage. Government agencies and policymakers should understand the importance of factors and dimensions from estimated weightage and develop policies such as National Rail Plan and Model Share for freight transport. These policies can help to reduce the gaps between the current position and various expected targets of the nations, such as Industry 4.0, Sustainable Development Goals, and Millennium Development Goals.

7. Conclusion

IoT is the initial stage towards achieving Industry 4.0, and this study moves one step forward in that direction. The current study identifies the IoT adoption factors under three contexts: Technology, Organization, and Environment. The study highlights the weightage of each dimension and the factors under the dimensions. The study finds that technological context is the most important concerning IoT adoption. The study shows the relative weight of factors under each dimension and the dependency weight of the factors. The findings exhibit that 'Competitive Advantage' is the most important factor, followed by Management Support, Security and Privacy, Technology Readiness and Capabilities, and Government Policy and Support.

Although the study has constraints, the inference could not reduce its values; instead, outcomes show some directions for future research. The study uses literature and expert opinions to identify the factors, but other techniques, such as brainstorming, could identify more realistic factors for the freight transport and logistics industry. Besides this, the study categorizes the factors in three contexts, but future research may include additional aspects, such as social.

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