Evaluating Roadblocks to Implementing a Green Freight Transportation System: An Interval Valued Intuitionistic Fuzzy Digraph Matrix Approach

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Abstract

Nowadays, freight logistics industries are seeking to adopt green freight practices in their transport systems to reduce environmental concerns; efficient green freight practices lead to reductions in greenhouse gas (GHG) emissions while using less energy and material. The freight logistics industry, despite its' significant contribution to a country's monetary development and economic welfare, is not well regarded because of its role in contaminating the climate. However, the freight logistics industry is trying to implement a green freight transportation system to improve their image with buyers. However, they are facing a lot of obstacles. Therefore, this paper seeks to identify the barriers to the implementation of green freight in first world and third world nations and formulate them into a single numeric index. The Interval-Valued Intuitionistic Fuzzy Set (IVIFS)-based graph theory and matrix approach (GTMA) technique has been used in this research to derive the green freight barrier impact index value. The PERMAN algorithm is used to compute the permanent function of matrices. Findings suggest that the freight logistics industries in third world nations should pay more attention to societal and managerial barriers for successful implementation of green freight. This research will assist policymakers and managers of freight logistics industries to create strategies to overcome the hurdles in properly implementing green freight practices.

Keywords: Green freight transportation; Barriers; Interval-Valued Intuitionistic Fuzzy Set; Graph theory and matrix approach, PERMAN algorithm

1. Introduction

“Freight transportation is not only a means of fulfilling one's desire by delivering products to their destination but also a link to have a positive impact on the nation's economy.” (Wang et al., 2020). These lines fully reflect the true meaning of freight transport. However, despite the contribution of freight transport (FT) to economic prosperity, its negative effects have changed its actual definition. In the last few years, freight transport has become the second highest GHG contributor in the world. This is because freight transport emits a fourth of the world's CO_2, making it difficult for people to survive day by day (Cristea et al., 2013). According to Torjesen (2021), freight transport not only greatly pollutes the environment, but it was also responsible for 8.7 million deaths globally due to air pollution from fossil fuels in 2018. Statistics suggest that freight movement (in tonne-km) will increase by more than 500% from 2017 to 2047, resulting in an almost 400% rise in emissions from freight traffic (India Energy Security Scenarios, 2047 n.d.). Freight services are not only essential for the economic prosperity of a country but also for social welfare. Demand for services has increased many folds in recent years, owing to rapid industrialization and faster growth of the domestic economy of many countries. Other contributory pressures are factors such as globalization and growth in international trade (Ding et al., 2021). Based on this increased demand, Salvucci and Tattini (2019) estimated that global demand for freight would triple from 2015 to 2050, thereby releasing double the CO_2 emissions with current mitigation measures. Modal shifting suggests that absenteeism will be the main cause for the continuation of transportation by high emitting trucks (Gota and Qamar, 2021). This would further exacerbate natural issues, for example, air contamination, a dangerous atmospheric deviation, environmental change and erosion of water resources (Gutiérrez et al., 2021). Therefore, to positively meet the demand of freight transportation, designing green freight transportation that utilizes eco-friendly resources and creates minimal ecological impact by following eco-accommodating practices is the need of the hour (Figure 1). Green freight proves to be beneficial from both environmental and economic levels (Strulak-Wójcikiewicz et al., 2021). It has become an indispensable option for firms to gain a competitive advantage by using their green image and to maintain sustainability in the face of growing environmental pressures (Kahupi et al., 2021). The Economic Survey of India shows that an improvement in freight efficiency will result in a reduction of indirect logistics costs by up to 10% and consequently a 5-8% increase in exports (NITI Aayog, 2018). Nonetheless, awareness about green freight transportation (GFT) among buyers is extremely confined, thus depolarizing the demand for such type of transportation in the marketplace. Due to the lack of strict enforcement of environmental regulations, senior executives often become resistant to accepting their responsibility towards green freight development and management (Majumdar et al., 2019, Tumpa et al., 2019). Although it is extremely important for industries to adopt green freight in its practices at global level, implementation is still in its infancy. Developing and technologically less advanced nations of Asia, Africa and Latin America are classified as third world nations. Their economies depend on the economies of developed countries. Problems often include unstable governments, high poverty, high child mortality, low economic and educational development and low self-consumption of their natural resources. According to Ferronato and Torretta (2019), compared to third world countries, first world countries have only 2% waste that is not disposed of, while due to lack of adequate systems, 93% waste in third world countries is burnt either on roads, on open ground or is thrown into waterways. First world countries and third world countries have many inequalities, their own challenges and their own plans to tackle them.

Consequently, it is necessary to comprehend what circumvents the extensive adoption of GFT in the context of first world nations and third world nations. There has been extensive work carried out on other aspects of green freight (Solomon et al., 2019, Sattanum, 2021). But surprisingly, no study has been conducted to explore this problem. Hence, this research adds to current literature on the obstacles encountered in the execution of GFT in these nations by addressing the following research questions.

i. What are the various barriers hampering GFT implementation in first world nations and third world nations?

ii. What is the importance of each barrier over the other barriers in this integrated framework?

iii. Which is the most significant barrier in implementing GFT in first world nations and third world nations?

iv. What implications does this current study provide in terms of practical applicability?

This investigation endeavours to answer the above questions through the accompanying objectives.

i. To explore the barriers influencing GFT implementation in first world and third world countries from literature and expert opinion.

ii. To assess the intensity of green freight barriers by calculating the green freight barrier impact index value in the same context.

iii. To compute the comparison coefficients of the main barriers and suggest some research implications of this study.

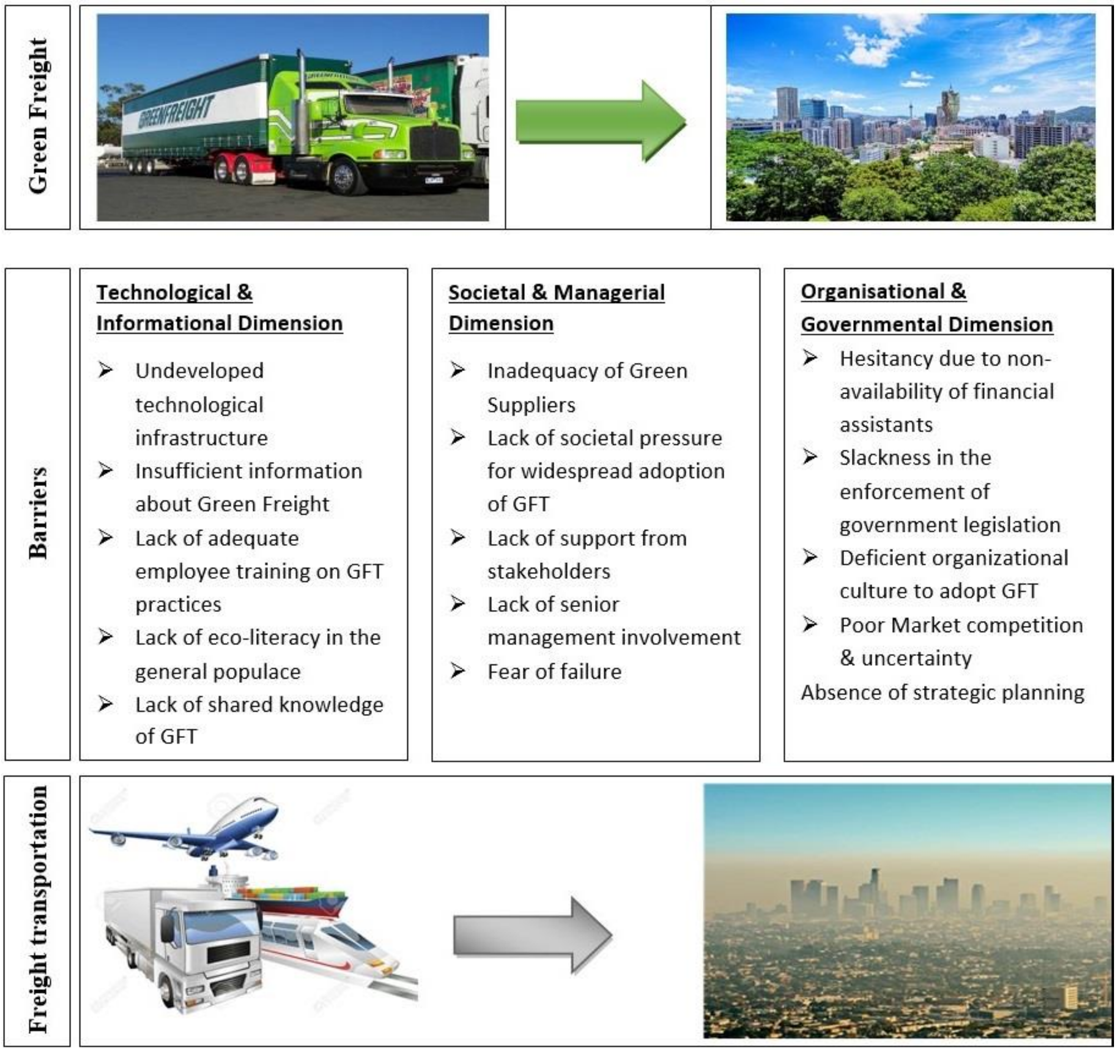

Figure 1: Layout of the Green Freight Transportation System

The present study makes several contributions to existing literature. Firstly, it expands the literature on freight sustainability by reviewing and finding constraints for the implementation of GFT. Secondly, a mathematical model is developed by integrating Interval-Valued Intuitionistic Fuzzy Set (IVIFS), graph theory and matrix approach (GTMA) using the PERMAN algorithm to determine the critical constraints that thwart the successful implementation of GFT in first world and third world nations. The literature review of the methods employed in section 2.5 shows that many researchers have used GTMA and IVIFS techniques in their studies (Rao et al., 2018, Chen et al., 2020). Yet no one has integrated GTMA and IVIFS (IVIFS-GTMA) using the PERMAN algorithm in the green freight scenario; this integration of IVIFS better deals with uncertain data (Zulkifli et al., 2021). The results of the present study can help logistics/decision-makers and policymakers of first world and third world nations to easily overcome the barriers obstructing successful implementation of GFT by predicting them. The implementation of green freight brings success which ultimately leads to economic benefits, competitiveness and a better, cleaner environment.

The paper is presented as follows. Related articles are reviewed in section 2. Section 3 examines the various constraints to GFT adoption. Section 4 explains the methodology used with section 5 validating the present framework through a case illustration. The results, managerial implications and future scope for study are discussed in sections 6, 7 and 8 respectively.

2. Literature review

In this section, we will sequentially review previously published studies related to our research problem.

2.1. Freight Transportation and Economic Development

Many authors have referred their research to freight transportation over the past decade due to economic development concerns (Liimatainen and Pöllänen, 2013, Fu et al., 2020,). Oliveira et al. (2018) analysed urban freight transport in Brazilian cities for the economic development of cities. The results promoted the importance of involving stakeholders in this development process. Zhu et al. (2020) implemented the complete decomposition method to pick out the drivers of freight transport and unearthed its intrinsic relationship with economic development in China. It was finally concluded that the rapidity of transport was the most crucial driver of the decoupling progress. Simultaneously, Godil et al. (2020) examined the relationship between transportation services and carbon emissions related to the US economy. This showed that green economy development is dependent on the introduction of technologies that reduce CO_2 emissions, promote economic growth and provide green transportation services. Solutions based on the sharing economy can play a role in the growth of sustainable urban freight transportation by lessening the number of freight vehicles and using more sustainable vehicles. Consequently, Strulak-Wójcikiewicz and Wagner (2021) evaluated the potential of the sharing economy to transport freight to Poland's cities.

2.2. Negative Externalities of Freight Transportation

Negative externalities emanating from the freight sector have also attracted the attention of authors. In this regard, Demir et al. (2015) gave rise to ideas of achieving improvement in future by conducting a thorough and helpful survey on the negative freight transport externalities included in existing literature. Later, Kellner (2016) came up with the aim of tackling the inadequacies in the field of assigning GHG outflows by moving from road freight transport systems to single shipments. Lebedevas et al. (2017) examined the stockpiles for lessening fuel utilization and ozone harming substance outflows into the environment when cargo was shipped by rail in Lithuania. Marcilio et al. (2018) examined ecological and performance factors in the lean and green manufacturing scenario in the road freight transport framework, identifying the most influential factors with the help of simulation exercises. They identified types of fleet delivery, fleet life and style of driving. Subsequently, Touratier-Muller et al. (2019) traced the reactions of small and medium-sized enterprises (SMEs) to compulsory and elective policies introduced by the French government; these demanded less carbon dioxide (CO_2) outflows produced by freight transportation. Pérez-Martínez et al. (2020) made an evaluation of urban road freight in the metropolitan area of Sao Paulo on the basis of a municipality survey; they investigated the energy used, the natural effects produced and the CO_2 outflows of road freight.

2.3. Sustainable Freight Transportation

All of these pieces of research highlight that freight transportation is an important area in the context of globalization and the economy, while its negative influence makes it harmful to the environment and humankind. Keeping all these aspects in mind, many efforts have been made by researchers to make freight transportation more sustainable. As such, Schliwa et al. (2015) prepared a novel framework that probes the calibre of cargo cycles to make city logistics more ecological while investigating approaches to empower their dissemination. Ellram and Murfield (2017) presented a well-organized review on the literature of conceptual and empirical studies published in the field of environmentally sustainable freight transport (ESFT) since 1990; they demonstrated that literature in this field has grown significantly since 2010. Buldeo Rai et al. (2018) proposed an extensive indicator method to superintend the sustainability of urban freight transport from the viewpoint of the local authority while Shankar et al. (2018) identified and assessed risks related to the sustainability of freight transport systems. Moreover, Bektaş et al. (2019) reviewed the contribution of operational research conducted in the context of making freight transportation green. Around the same time, Demir et al. (2019) discussed bi-target planning and the examination of trade-offs among costs and CO_2 emanations in intermodal freight transportation. Sivanandham and Gajanand (2020) have proposed platooning to make socio-economic benefits in the context of the sustainable transportation industry. Platooning is an innovative transportation practice that can hopefully tackle the issues of the burgeoning transportation industry. In the same tradition, Pathak et al. (2021) attempted to build a unified performance evaluation structure that relies on competing priorities for sustainable freight transport (SFT) systems; at the same time, they assessed and prioritized critical success factors for SFT based on competitive priorities.

2.4. Research Gap

It can be deduced from green freight-based literature that there has been a lot of research in the freight logistics sector focused on the goal of sustainability. The topics addressed in literature provide a clear understanding of how green freight and a nation's economy are connected to each other. GHG emissions have affected freight logistics, resulting in initiatives in the development of the freight sector to maintain its sustainability. In 2019, Alagesan and Daud (2019) investigated constraints to execute a green road freight transport system in the Malaysian context; these included policies and laws, cross-border services, level of awareness and readiness, technological cost and vehicle routing. Yang et al. (2019) have identified barriers and opportunities in Chinese operations to make long-distance trucking more efficient. The resulting market fragmentation, fuel consumption rules, independent technology validation, real-world testing programs, financial incentives and subsidies for green technologies are significant constraints. Singh et al. (2021) have examined the constraints of green freight execution in India. In this work, information distortion, lack of commitment by top management and lack of strategic planning have been recognized as significant constraints through the ISM-gDEMATEL technique. Pfoser and Management (2021) assessed 15 barriers to multimodal transport using the ISM method. External costs, internalization, versed information systems and education improvement are cited as the most important measures. Mostafa et al. (2019) and some other researchers have identified obstacles to green road transport, collaborative freight transport and some other specialized modes of transport (Solomon et al., 2019). However, this study attempts to recognize the barriers to implementing green freight in first world and third world nations and compares them by applying a specialized integrated technique. With expanding globalization, the significance of green freight transportation has become more articulate and deepened. This highlights the requirement for thorough implementation of GFT through innovative research. Therefore, this paper attempts to fill this gap and make the overall implementation of GFT successful through the objectives set out in Section 1.

2.5. A literature review of IVIFS-GTMA

Much research has been carried out to assess the bottlenecks within the supply chain sector. Malhotra et al. (2012) have applied graph theory and matrix approaches to provide an understanding of the constraints of reconfigurable manufacturing systems, including their relative interdependencies. The GTMA technique gives an index of constraints that evaluates the inhibitory power of these constraints. Attri et al. (2014) employed a graph theoretical approach to compute the potency of bottlenecks in the execution of total productive maintenance. A permanent function is derived from the digraph of the obstacles obtained by this technique; this proved to be helpful in finding the potency of these obstacles. Virmani et al. (2021) analysed the barriers to Industry 4.0 adoption using graph theory and a matrix approach and ranked them in descending order of priority. Dahooie et al. (2019) applied interval-valued intuitionistic fuzzy CODAS in their research to find suitable software to implement cloud computing. Singh et al. (2021a) have proposed an intuitionistic fuzzy set based modified TOPSIS and VIKOR method for the evaluation and fair selection of lean six sigma projects. The weighted average has been chosen to collect the experts' suggestions and the entropy measures have been used to calculate the weighting of the selection criteria. Modified TOPSIS and VIKOR have been used to rank the projects. Tiwari et al. (2020) have exercised the use of an interval-valued intuitionistic in conjunction with TOPSIS for supplier selection. This work attempts to integrate both GTMA and IVIFS methods to provide better accuracy in results by performing unbiased calculations from linguistic input data.

2.6. Barriers influencing the implementation of GFT

An important topic in current literature is the proposal of a suitable model to analyse and disclose the relationships between various factors (Tran et al., 2020). This model building activity begins with a survey of the literature and ends with the selection of the most influential factor. Keeping this objective in mind, we have collected factors from various research papers and scientific reports. Thereafter, expert opinion finalized the main factors from the list of these literature-based factors. Obstacles are classified into key dimensions as per the suggestions of the experts. They are classified under three dimensions on the basis of similar traits; these are technological and informational, societal and managerial plus organisational and governmental as shown in Table1-Table 3 (Online Appendix (A1)). Detailed information about these factors and their sub-factors is given below.

2.6.1. Technological and Informational factors (TI)

Industries need to develop and keep up to date with new trends and technologies while implementing GFT (Ortiz, 2020). They should also establish a good infrastructure to incorporate new practices. A new transport system must include various technological advances combined with already existing technologies when significant changes are being made to the processes. Subsequently, this section presents factors associated with technology and infrastructure that affect GFT implementation in the context of first world nations and third world nations. A detailed description of sub-factors of this factor is given in Table 1 (Online Appendix (A1)).

2.6.2. Societal and Managerial factors (SM)

Social and managerial factors are factors originating from the general populace and issues at management level. They are caused by concern about the environment, responsibility, attitude and situation (Kumar and Anbanandam, 2020). This section presents a detailed description of societal and managerial factors affecting GFT implementation. A detailed description of sub-factors of this factor is given in Table 2 (Online Appendix (A1)).

2.6.3. Organisational and Governmental factors (OG)

Organisational factors involve characteristics, resources and the attributes of a firm, while governmental factors involve rules, regulations and policies implemented by the government (Qi et al., 2008). Factors such as 'hesitancy due to non-availability of financial assistance' and 'slackness in the enforcement of government legislation' affect the execution of GFT to a large extent. This section discusses various organisational and governmental factors which influence GFT implementation. A detailed description of sub-factors of this factor is given in Table 3 (Online Appendix (A1)).

3. Proposed IVIFS-GTMA integrated framework using the PERMAN algorithm

3.1. *Interval-Valued Intuitionistic Fuzzy Set (IVIFS)*

This section provides a brief overview of Interval-Valued Intuitionistic Fuzzy Set (IVIFS), Graph theory and Matrix approach (GTMA) plus the PERMAN algorithm; these are considered to propose an integrated framework of IVIFS - GTMA using the PERMAN algorithm. Though fuzzy sets find widespread use in decision making, they remain unable to measure the degree of uncertainty in human decisions. To overcome this issue, intuitionistic fuzzy sets (IFS) have been introduced as an alternative to facilitate the measurement of membership degrees, non-membership degrees and hesitancy degrees associated with the judgement of decision makers.

This feature of IFS assists decision-makers to determine their choices more accurately by considering the degree of disagreement. As an extension to IFS, Atanassov and Gargov (1989) introduced IVIFS, as the former lacks the capability to reflect human thinking more comprehensively. IVIFS proposes the use of interval values to denote the membership function, the non-membership function and the hesitation function instead of using crisp values to overcome the limitation of IFS. IVIFS has received a lot of attention from many researchers since its inception and has thus been used in many studies (Tiwari et al., 2020; Dahooie et al., (2019; Singh et al., 2021a). In this study, we have integrated IVIFS with graph theory and matrix approaches to detect the adverse effect of factors on GFT implementation.

3.2. *Graph Theory and Matrix Approach (GTMA)*

GTMA is useful in analysing the directional graphs of factors through visual evaluation. This is reliable even when the number of nodes is large and the graphs become complicated to visualize. In the past, these benefits have attracted researchers to utilize the advanced theory of graphs for modelling and analysing real-life problems in various fields, including areas such as material selection (Rao and A, 2006), manufacturing (Jain and Raj, 2016), logistics (Gupta et al., 2020), total quality management (Grover et al., 2004) and supply chains (Singh et al., 2019). These scholars have stimulated us to apply this method in our research.

GTMA is a logical and systematic approach of combinatorial mathematics arising from the advanced theory of graphs and networks. It has proved to be a powerful tool for modelling and analysing stochastic processes, transport networks, operation research and many other kinds of systems (Muduli and Barve, 2013). This approach presents a visualization of problems through a directional graph. The graph representation consists of multiple nodes and directed edges, where the nodes characterize the attributes and the directed edges denote inter-relationships between these attributes (Muduli et al., 2013). GTMA includes the following elements:

i. Digraph portrayal for visual analysis of the system and its factors

ii. Representation of factors and their inter-relations as a matrix for computer processing

iii. Calculation of permanent function that is appropriate for demonstrating the impact of every factor by a single index.

GTMA has advantages over other traditional representations such as causal diagrams, block diagrams and flow charts that are also valuable for visual examination. GTMA is able to depict interactions between all factors and can also be mathematically processed or expressed; there are limitations in the other techniques (Jain and Raj, 2016; Grover et al., 2004). The present study aims to quantify the effect of GFT adoption constraints in first world and third world nations; this is not possible in any of the above methods apart from GTMA.

3.3. *PERMAN algorithm*

The PERMAN algorithm was first developed by Nijenhuis and Wilf (2014) to calculate a permanent function of an $n \times n$ matrix. This paper incorporates the PERMAN algorithm rather than Ryser's method since Ryser's algorithm is not the most efficient algorithm for computing the permanent function of a square matrix; the PERMAN algorithm is. Ryser's formula requires about $n^2 \times 2^{n-1}$ operations for the computation of the permanent function while PERMAN requires only $n \times 2^{n-1}$ operations. This variation saves half of the work needed, making the PERMAN algorithm faster and more efficient in cases for a large number of targets (Crouse et al., 2017). The method of computing the permanent value is the same as that of the determinant. In order to avoid loss of information, negative signs are replaced by positive signs during calculation. One way to calculate the intensity of bottlenecks in a particular organisation is the *PERMAN function*.

3.4. *Proposed integrated framework*

The accompanying section presents the proposed IVIFS-GTMA unified system. The proposed methodology incorporates IVIFS and GTMA techniques by utilizing the PERMAN algorithm to identify significant barriers to GFT implementation. It is also appropriate to show the relative importance of constraints with their causal relations to provide a context for decision making. Figure 2 (as shown in online Appendix A1) depicts the flow chart of the proposed method, IVIF-GTMA. A detailed description of all steps involved in the quantization of factors is given in online Appendix A1.

4. Application of the Proposed Framework

The unified multi-criteria decision-making technique has been employed to study and to compare the repressing effects of different GFT execution hindrances in first world nations and third world nations. The detailed demonstration of the proposed framework is described here.

4.1. Selection of Respondents and Data Collection

The barriers affecting the implementation of green freight have been identified through an extensive literature review with experts being consulted to ensure their pertinency. In this regard, 35 experts were approached for the initial phase of data collection; 24 experts completed the response sheet, providing a response rate of 68.57%. 20 (83.33%) were industry experts and the other 4 (16.67%) were academic researchers in the field of supply chain and logistics. 6 (30%) experts belonged to the public sector and 14 (70%) from private institutions. Out of 20 experts, 4 (20%) were Sales Managers, 5 (25%) Logistics Managers, 3 (15%) Head of Freight Sales, 2 (10%) Transportation Managers, 2 (10%) Logistics Specialists, 4 (20%) Inbound Logistics Coordinators. All the sub-barriers have been finalized after taking inputs from experts; as shown in Table1-Table 3 (Online Appendix (A1)). Thereafter, a questionnaire (refer to Appendix A2) was prepared to obtain opinions from experts in terms of assessing and calculating the interdependence of the impact of each constraint on GFT implementation in first world and third world nations. This questionnaire was based on the Likert scale. The entire activity of collecting input was done through email services with the study conducted in the summer of 2021.

Table 4: The IVIF-GTMA preference scale

Linguistic Preference scale	No influence	Low influence	Medium influence	High influence	Very high influence
IFS	(0.10, 0.80, 0.10)	(0.25, 0.60, 0.15)	(0.50, 0.40, 0.10)	(0.75, 0.20, 0.05)	(0.90, 0.05, 0.05)
IVIFS	([0.050, 0.150], [0.750, 0.850], [0.000, 0.200])	([0.175, 0.325], [0.525, 0.675], [0.000, 0.300])	([0.450, 0.550], [0.350, 0.450], [0.000, 0.200])	([0.725, 0.775], [0.175, 0.225], [0.000, 0.100])	([0.875, 0.925], [0.025, 0.075], [0.000, 0.100])

Sources: Abdullah et al. (2019)

4.2. Computing the Green Freight Barrier Impact Index Value influencing GFT Adoption

This section includes the calculation of the green freight barriers impact index value for the adoption of green freight in first world nations and third world nations. The various steps involved in the proposed approach are given below:

4.2.1. Digraph representation

The GFT digraph has been developed; it looks at the three main factors and their degree of interdependencies as shown in Figure 3. Interdependencies between these factors are developed with the help of expert opinion. The digraphs have also been developed for sub-factors of each category that affect a particular category of factors (Figure 4). These digraphs consist of nodes and directed edges, where nodes represent factors ($E_i's$) and different edges illustrate their mutual interactions ($r_{ij}'s$). In the digraph, the r_{ij} implies the degree of dependence of the j_{th} factor on the i_{th} factor and is depicted as a directed edge from node i to node j.

4.2.2. Matrix representation

A digraph is a visual appraisal of factors, so it helps the analysis only to a limited extent. To establish the expression for GFT barriers, the digraph is represented in matrix form derived from Equation 1. The matrix representation of the GFT barrier digraph provides a one-to-one representation. This is an $n \times n$ matrix and considers all the constraints and their relative importance; for our case it is 15×15. The matrix representation of 15 intercepts is shown in Table 5.

4.2.3. Computational steps of E_i and r_{ij} values using IVIFS

Step 1. Gather linguistic responses from decision makers (DMs) through IVIFS preference scales constructed using Equations (2.3) - (2.5) (refer to Appendix A1), as shown in Table 4.

Step 2. Formulate the weights of DMs; these are displayed in Table 4. They are calculated using Equations (2.3) - (2.7) (refer to Appendix A1) in IVIFS instead of IFS.

Step 3. Construct the aggregated judgment matrix. The IVIFS score, given by k_{th} decision maker reflects the influential level of criterion i over criterion j. Using Equation 2.6 (refer to Appendix A1), the DM's preferences are aggregated; this subsequently displays all the r_{ij} values by generating a matrix of 15×15.

Step 4. Acquire the crisp values for r_{ij} using Equation (2.7) (refer to Appendix A1). These crisp values can be seen in the 15 × 15 matrix displayed in Table 5.

Step 5. Repeat steps 3 and 4 to obtain the crisp values of E_i for first world nations and third world nations. These values are set out in Table 6.

4.2.4. Computing the Green Freight Barrier Impact Index Value from the Crisp Relation Matrices

The GF barriers impact index value is formulated for first world nations and third world nations through the PERMAN algorithm explained in Equations (3.1) to (3.5). To calculate the index value, the value of E_i is replaced according to the case. In addition, the index value of each main factor is drawn from 15 × 15. Thereafter, theoretical best values and worst values are obtained for each factor. Correspondingly, the coefficient of similarity for the related case is calculated for the comparative purpose using equations (4.1) - (4.2), as shown in Table 7.

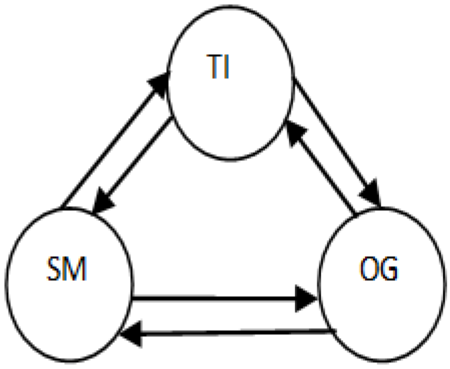

Figure 3: The behavioural digraph of the factors

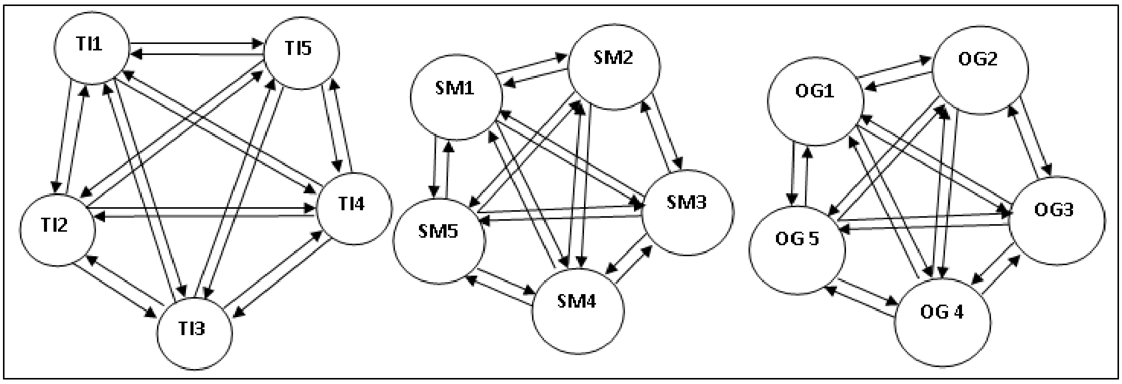

Figure 4: The behavioural digraph of the sub-factors

Table 5: Crisp values of r_{ij}

OG5	0.004	0.029	0.056	0.004	0.029	0.016	0.016	0.016	0.056	0.029	0.009	0.009	0.056	0.016	E15
OG4	0.004	0.029	0.016	0.029	0.056	0.056	0.016	0.016	0.029	0.029	0.004	0.009	0.016	E14	0.984

	TI1	TI2	TI3	TI4	TI5	SM1	SM2	SM3	SM4	SM5	OG1	OG2	OG3
TI1	E1	0.016	0.029	0.029	0.016	0.029	0.009	0.029	0.009	0.004	0.004	0.004	0.016
TI2	0.984	E2	0.016	0.056	0.009	0.056	0.056	0.029	0.029	0.016	0.009	0.016	0.009
TI3	0.971	0.984	E3	0.016	0.029	0.029	0.004	0.029	0.016	0.029	0.004	0.004	0.029
TI4	0.971	0.944	0.984	E4	0.004	0.016	0.056	0.009	0.029	0.016	0.004	0.016	0.009
TI5	0.984	0.991	0.971	0.996	E5	0.029	0.009	0.029	0.009	0.029	0.009	0.009	0.016
SM1	0.971	0.944	0.971	0.984	0.971	E6	0.016	0.056	0.029	0.056	0.016	0.016	0.004
SM2	0.991	0.944	0.996	0.944	0.991	0.984	E7	0.029	0.029	0.004	0.009	0.056	0.009
SM3	0.971	0.971	0.971	0.991	0.971	0.944	0.971	E8	0.029	0.029	0.056	0.009	0.004
SM4	0.991	0.971	0.984	0.971	0.991	0.971	0.971	0.971	E9	0.029	0.009	0.009	0.016
SM5	0.996	0.984	0.971	0.984	0.971	0.944	0.996	0.971	0.971	E10	0.009	0.016	0.004
OG1	0.996	0.991	0.996	0.996	0.991	0.984	0.991	0.944	0.991	0.991	E11	0.009	0.029
OG2	0.996	0.984	0.996	0.984	0.991	0.984	0.944	0.991	0.991	0.984	0.991	E12	0.004
OG3	0.984	0.991	0.971	0.991	0.984	0.996	0.991	0.996	0.984	0.996	0.971	0.996	E13
OG4	0.996	0.971	0.984	0.971	0.944	0.944	0.984	0.984	0.971	0.971	0.996	0.991	0.984
OG5	0.996	0.971	0.944	0.996	0.971	0.984	0.984	0.984	0.944	0.971	0.991	0.991	0.944

Table 6: Crisp values of E_i

Sub-Barriers	First world countries	Third world countries
TI1	0.0091	0.0287
TI2	0.0163	0.0558
TI3	0.0287	0.0287
TI4	0.0287	0.0558
TI5	0.0163	0.0558
SM1	0.0163	0.0287
SM2	0.0091	0.0558
SM3	0.0163	0.0287
SM4	0.0091	0.0558
SM5	0.0163	0.0163
OG1	0.0287	0.0287

OG2	0.0163	0.0287
OG3	0.0091	0.0163
OG4	0.0163	0.0287
OG5	0.0287	0.0558

5. Results and Discussion

Table 7 portrays the impact index values of different obstructions for first world countries and third world countries. The index values of a specific obstruction determine the level of its unfavourable impact on the implementation of green freight practices. Higher values of the index indicate more disruption in the implementation of GFT practices, while lower values indicate less disruption. In adopting GFT, the calculated green freight barrier index can be utilized to ascertain the suitability of companies corresponding to different nations. Lower index values depict less hostile effects and designate that a specific nation's company might be more suitable for GFT implementation. This section describes the results obtained from the IVIFS-GTMA framework from both graphical and theoretical perspectives.

5.1. Overall Analysis

Table 7 illustrates the complete analysis of the main factors by showing their index value. The best value of a barrier is found by assigning the best value to all its sub-barriers. At the same time, the worst value is achieved by assigning the worst value to all its sub-barriers (Mangla et al., 2019). The index value of 16479000 for third world countries is very close to its worst value and the coefficient of similarity in terms of this worst value, *i.e.* 0.610, makes it clear that successful implementation of green freight is most constrained among third world countries. In addition, the index value for first world nations is 15109000 and the coefficient of similarity in terms of its best value is 0.147. This data proves that these nations also face considerable hurdles in the implementation of green freight, although the adoption of GFT in these countries is slightly easier than in third world economies.

5.2. Analysis of the main factors

Societal and managerial barriers were shown to be the biggest hurdles in implementing GFT in the companies of third world nations. The index value of 0.0883 is nearer to the worst value for third world countries compared to first world countries, indicating that the industries of these third world economies should take more care during GFT implementation than companies of first world nations. Barriers includes inadequacy of green suppliers, lack of societal pressure for widespread adoption of GFT, lack of support from stakeholders, lack of senior management involvement and fear of failure. In terms of the best value for SM, first world nations are nearer to the best value of the barrier, meaning that it is easier for companies in these nations to implement GFT. The results found are similar to those of a study by Mostafa et al., (2019) which suggests that market structure, regulations, the behavior of partners and their relationships are the most important constraints. Senior management need to understand the strategic competitive advantages of green freight implementation. Lack of involvement of senior management in implementation of green freight is a major impediment. It is also claimed to be a crucial driver of the adoption of eco-sustainable practices (Longoni et al., 2018). Although the lack of societal pressure for widespread adoption of GFTs is significant, the inadequacy of green suppliers to procure the required sustainable raw materials is essential. Lack of support from stakeholders can hinder an organization in connecting with markets worldwide. Stakeholder support helps industries deal with the pros and cons of every aspect of business and can spot volatile customer demand patterns in these uncertain times. Also, there is a need to organize training and educational programs on a regular basis to overcome the fear of failure.

Table 7: Index Values of Various Barriers for First World Nations and Third World Nations

		INDEX Value	Best Value	Worst Value	Csi	Csi'
Overall Analysis	First world nation	15109000	14279270	19923500	0.147	0.853
	Third world nation	16479000			0.390	0.610
TI	First world nation	0.0266	0.023	0.0544	0.115	0.885
	Third world nation	0.0328			0.312	0.688
SM	First world nation	0.0717	0.0639	0.1263	0.125	0.875
	Third world nation	0.0883			0.391	0.609
OG	First world nation	0.0145	0.0133	0.0299	0.072	0.928
	Third world nation	0.0156			0.138	0.861

For technological and informational (TI) barriers, it is clear that the index value of 0.0328 for third world nations compared to first world nations is nearer to the worst value, showing that the barriers of TI are more crucial for third world nations embracing GFT. The sub-barriers under this category are undeveloped technological infrastructure, insufficient information about green freight, lack of adequate employee training on GFT practices, lack of eco-literacy in the general populace and lack of shared knowledge of GFT practices. Most third world countries suffer from underdeveloped technological infrastructure, the backbone of any new technological implementation. At the same time, organizations that have insufficient knowledge about green freight worry about taking initiatives and their financial implications, thereby opposing the adoption of GFT. In order to take green freight initiatives, there is a need to create adequate employee training on GFT practices to ensure fiscal and mental comfort. Environmental awareness should be included in the curriculum at the academic level for young people to tackle the lack of eco-literacy among the general public. Staff members should share their experiences with each other.

The final major barriers to GFT implementation are organisational and governmental (OG) factors. This dimension consists of hesitancy due to non-availability of financial assistance, slackness in the enforcement of government legislation, deficient organizational culture to adopt GFT, poor market competition and uncertainty plus absence of strategic planning. For these types of barriers, the worst value is closer to that of third world nations compared to first world nations. This indicates that these (OG) barriers are more influential for third world nations. The intricacy of OG barriers in relation to third world nations will be higher than for first world nations. The "hesitancy due to unavailability of financial assistants" demands a plausible explanation. This suggests that third world countries do not have sufficient incentives to encourage their practitioners to promote and engage in a green freight transport system. Another explanation could be that existing incentive policies fail to cover the additional costs of adopting green practices, discouraging practitioners to adopt GFT. Adoption of GFT needs to be encouraged by the government through various subsidies on green materials, or by imposing heavy financial penalties on polluting practices. An efficient and practical legislative framework is essential to ensure a conducive business environment for implementing GFT initiatives by introducing a strategic policy framework. As a result, many countries, including third world countries, are already enacting appropriate legislation to increase the adoption of GFT. Competitive pressure from opposing sides also leads to embracing sustainability practices (Ashrafi et al., 2019).

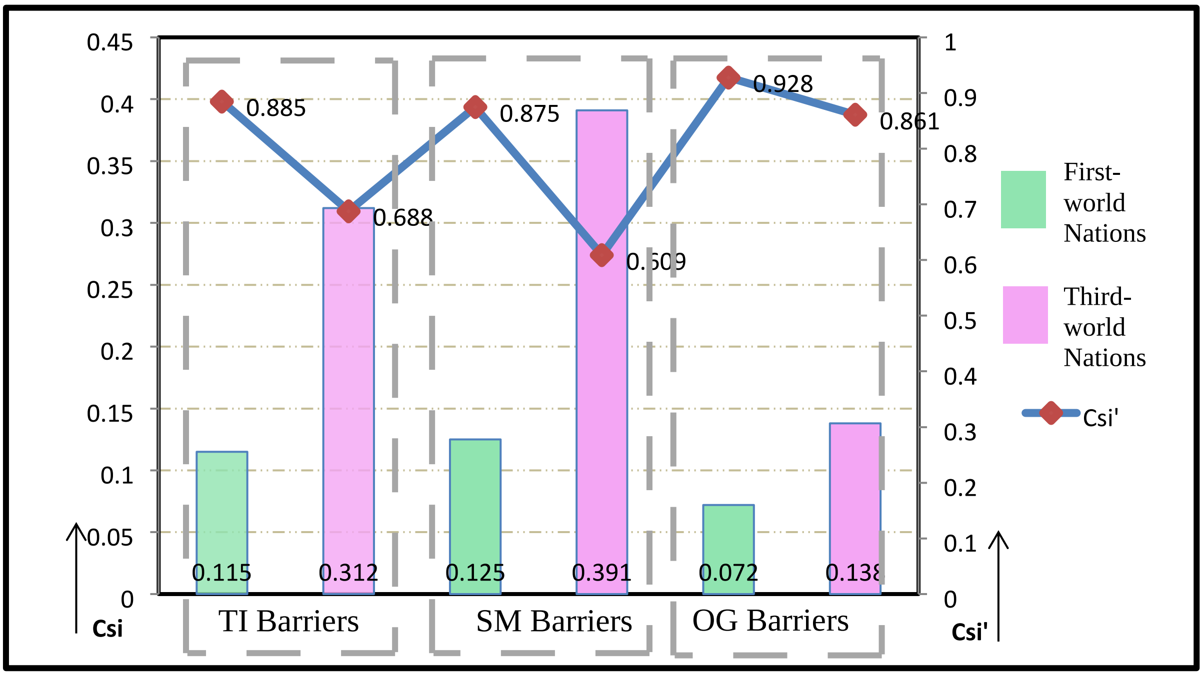

Figure 5: Graphical Representation of the Coefficient of Similarity

A graphical representation of the best and worst values with respect to the coefficient of similarity is shown in Figure 5. This figure provides one-to-one comparative results of constraints. Figure 5, based on Table 7, illustrates that in third world nations, societal and managerial are the most effective barriers with a C_{si} value of 0.391. Thereafter, the most effective barriers are technological and infrastructural constraints (C_{si} = 0.312); next are organizational and governmental constraints with a C_{si} value of 0.138. Among these, the least influencing barriers are organizational and governmental barriers. Among first world countries, societal and managerial barriers were the most influential barriers with a C_{si} value of 0.125, while technological and infrastructural barriers were the second most influential barriers with a coefficient value of 0.115. The next least influential barriers are organizational and governmental with a value of 0.072.

6. Sensitivity Analysis

In this study, a sensitivity analysis has been designed to examine the favouritism and reliability of the inputs received by respondents. In this general case, stated as case-1, equal weightage has been delivered to all the experts; in the other twenty-four cases, one is given more, and the other is given equal weightage. Therefore, the values of C_{si} have been obtained for the whole twenty-five cases to be different. Figure 6 clearly shows that the intensity of all the constraints remains almost unchanged even after assigning different weights to the respondents. Therefore, we can say that there is no unfairness in the results of this analysis.

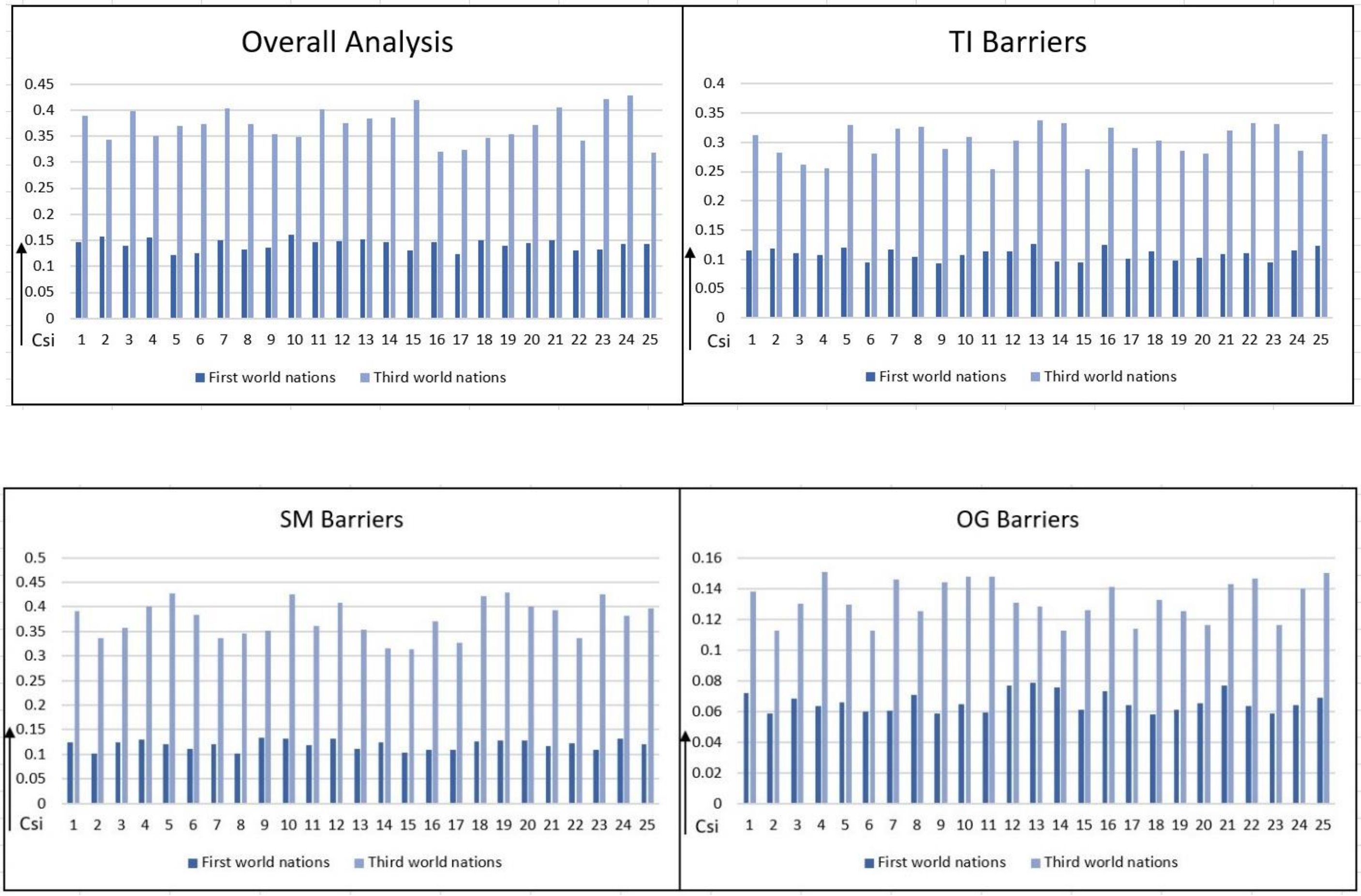

Figure 6: Sensitivity Analysis of Barriers

7. Theoretical and Practical Contributions

7.1. Theoretical Contributions

The present study provides a multi-pronged contribution to the limited existing knowledge in the sustainability of freight transport and provides insight into the barriers to greening freight transport. Additionally, it explains and quantifies important constraints to the adoption of green freight transportation. This research has utilised IVIFS-GTMA to delineate the inter-relationships among all identified barriers to green freight. The PERMAN algorithm establishes impact indices for constraints with reference to first world countries and third world countries. The proposed model has not been used by any previous researchers to derive the impact index values of green freight barriers in the context of developed and developing nations. With the help of the indices derived by the permanent function of matrices and the experienced opinions of experts, the constraints are prioritized on the basis of their influencing powers. As a result, uncovering constraints and their inter-relationships will help future researchers to better understand not only these relationships but also their influencing power. Thus, this paper explains a robust methodology by presenting IVIFS-GTMA with the PERMAN algorithm and contributes to the research field by delineating and exploring the connections between various constraints.

7.2. Practical Contributions

At present, due to many crises such as hurricanes, pandemics etc., various issues have arisen at global level, with their main focus on environmental change. In such unimaginable times, green freight can prove to be helpful in improving the social performance of organizations and to gain competitive advantage as green freight comes under the category of ecological initiatives. Consequently, it can be said that there is a need to adopt green freight in industries. Thus, this research leaves a wide impression in the context of implementing green freight. It enhances understanding about the barriers hindering implementation of green freight in both developed and developing countries.

The presented IVIFS-GTMA model with PERMAN algorithm and delineated inter-relationships among the various barriers will help policymakers and managers to formulate appropriate policies and strategies for implementing GFT. To overcome these barriers, engineers and managers can prioritize them based on the obtained impact index values for each barrier in relation to the others. The impact index value of barriers, calculated for each case in developed countries and developing countries, may enable decision makers in these countries to prioritize green freight barriers and address them accordingly. In terms of developing countries, where societal and managerial barriers are the most influential constraints, managers and engineers should pay more attention to the mitigation of these barriers. Likewise, this research will assist managers to focus on the major barriers to implementing green freight in both developed countries and developing countries. Moreover, information from the barriers assessment can be used to increase the adoption of green freight.

7.3. Implications for Managers and Policy Makers

The results of this study have produced significant implications for managers and policy makers in the freight industry towards green freight adoption; this paper will help to overcome the barriers faced by them in a strategic manner. A comprehensive understanding of the key constraints and their removal will lead to successful implementation of green freight. Moreover, the relative ranking of the constraints will help managers to channel their efforts in the right direction and formulate suitable strategies accordingly. Self-evaluation and self-actualization of any deficiencies can be better viewed by computing the permanent working value of each category of constraint. Necessary measures can be taken to remove any bottlenecks, providing a roadmap for green freight implementation. Thus, the results will be extremely useful for industrialists and businessmen who are keen to convert their freight logistics businesses from a traditional to a green industry. Ultimately, adoption of green freight will lead to a reduction in trips, controlled emissions, improved air quality, reduced waste, achieving sustainability, contribution to a sustainable economy and improved profitability.

8. Conclusion

Logistics industries have been a major contributor to increasing air pollution and greenhouse gas emissions. Consequently, it is requisite for these industries to embrace green freight practices to attain a more prominent worldwide competitive advantage and an improved brand image. Green freight practices are being widely adopted by various logistics industries in many developed countries, but they are facing many hurdles in their implementation. As a result, managers in other countries have ruled out its implementation due to the obvious constraints. To alleviate these concerns, this paper gives a comprehensive strategy for dealing with potential bottlenecks using IVIFS-GTMA. The relative ranking of barriers to green freight adoption has been assessed. The obstacles encountered are listed as societal and managerial constraints, technological and infrastructural constraints followed by organizational and governmental constraints in decreasing order of priority. Managers, industrialists, businessmen and policy makers can use this method as a benchmark. They will be able to calculate and compare the relative intensity of bottlenecks and prepare a comprehensive green freight index (GFI) for their organisations.

There are some limitations in this study. Green freight is a broad and emerging area of research. Therefore, listing and estimating all potential constraints cumulatively can be tedious and subject to errors. In addition, the IVIFS-GTMA method uses expert input to perform all calculations. Any laxity in recording and assessing responses may result in inaccurate results. Hence, careful data collection and assessment is imperative.

This investigation provides some directions for future studies. The present context can also be extended to the Neutrosophic set or other modified fuzzy sets under the circumstances of indeterminant DM judgment. Its average operator, i.e., IVIFWA, can also be improved by applying another new aggregation tool. Furthermore, the sensitivity of decision-makers' loads to preference outcomes has not been investigated in this research. As a result, a more recent sensitivity analysis can be investigated as a future research direction.

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