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Factors Affecting Container Shipping Through Inland Waterways

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Abstract

Inland waterways in India have shown positive growth over the last 10 years. The mode of transport is very promising, yet desired volumes are yet to be achieved. In 2018, India started its first domestic container shipping and the first export of container shipping through inland waterways in 2020. This research work expedites the identification of various prominent factors using the fuzzy analytic hierarchy process method. Four major factors were considered based on feedback from experts, and using the said method, factors and subfactors were ranked globally. Among the four factors we considered, infrastructure factors were found as the most critical factor, followed by economic factors, geographical factors, and, lastly, regulatory factors. Moreover, as per the weights obtained for the subfactors, inadequate river depth of rivers, container inventory, and repositioning emerged as significant factors that need to be addressed. Finally, this research paper puts forward steps necessary for boosting the growth of container shipping through inland waterways.

Keywords: Inland waterways, Container shipping, Fuzzy AHP, MCDM

1. Introduction

Inland waterways provide a viable alternative to road and rail transport and are very desirable, especially from the perspectives of cost and sustainability. Various studies have established that inland water transport (IWT) is economical, fuel efficient, and environmentally friendly. India's previous history indicates that river transport was used extensively by the Mughals and later by the East India Company. After independence, the development of waterways was neglected. Apart from technical and geographical issues, to improve the situation, the Inland Waterways Authority of India (IWAI) was established in 1986 to develop and regulate inland waterways. In this process, the IWAI was mandated to develop shipping and navigation.

However, an insignificant focus was given to IWT [1]. With the National Waterways (NWs) Act of 2016, India has taken forward the development of NWs. Currently, various developmental works are being implemented in different waterways. However, its adoption by users, manufacturers, and shippers is yet to crystallize in a large way. The country has an ambitious plan to develop inland waterways with a target to achieve 100 MT by 2022 from the current traffic of 72 million tons in 2019 and 130 million tons by 2025. Inland container traffic commenced in 2018. The export of steel scrap through containers to Bangladesh in the year 2020 by the Adani group has been a landmark of container movement in India's inland waterways. The government has initiated landmark schemes, such as SagarMala, to develop coastal shipping and link various inland waterways with the coastal shipping network. Due to the growing containerization of the cargo world, which reduces pilferage, flexibility in unitization, and convenience of handling, there is a need to develop a strategic plan and framework to increase container use in inland waterways in India. Recent trends in reducing carbon footprint and innovation in low-carbon emission fuels make inland waterways viable.

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The last two decades have seen significant growth in the domestic traffic of bulk cargo in these waterways. However, there is a need to study the factors and efforts required for the considerable growth of container traffic. A substantial body of research has been conducted in exploring various studies related to the domain in the literature review in Section 2. The section also explores the development of IWT over a certain period in the country, previous studies related to IWT, and factors affecting IWT. The research methodology and analysis are discussed in Sections 3 and 4, respectively. A detailed conclusion of the study is brought forward in Section 5.

2. Literature Review

Water transport forms a part of the entire transportation system in a country and is invariably not door-to-door by its very nature. While waterways are naturally formed in many countries, they are not fully utilized to their potential because manmade infrastructure are still needed and are not made available. The water transport does not cover the first mile and last mile, so we consider it a part of multimodal operations. We need funds to be identified to create the necessary infrastructure, and tradeoffs are assessed to match with benefits. Tradeoffs normally involve increased time and cost associated with mode switching via ports and jetties, among others. National governments play a significant role in these arrangements. National IWT is defined as "the movement of goods or people on 'inland waters' between two places located in the same country even if transiting through a second country" [2]. IWT explicitly excludes "sea" and coastal shipping [3].

Inland waterways are more suitable for bulk cargoes than unitized/breakbulk cargoes because the speed, consolidation, and intermodal dependence for the first and last miles are higher [4].

Inland waterways provide an alternative to road and rail transportation, especially for containerized transport. It also offers an emergency alternative to natural and manmade disasters. IWT reduces the emphasis on land-based facilities and provides increased transportation capacity and redundancy without further land demands. The IWAI has been testing the commercial viability of container transport by IWT for some time now in India. Pepsico's 16 TEU consignment of foods and snacks was moved from Kolkata to Varanasi in October 2018. In November 2019, the Indian government, 53 TEUS of petrochemicals, edible oil, and beverages were moved from the Haldia Dock Complex to the Guwahati Pandu Port as a mark of a good connectivity to the northeastern region of India. In July 2019, Adani Logistics carried 52 containers on NW-1 from Haldia to Patna, and container cargoes were also sent earlier from Kolkata to Varanasi. In July 2020, Adani Logistics completed its first-ever containerized cargo export (45 TEUs) from India to Bangladesh utilizing inland waterways. Thus, the Indian government is committed to improving the features of IWT and making it attractive and reliable, and customers are also ready to explore the possibilities.

However, we need supporting infrastructure, communication, and navigation technology to integrate IWT into a multimodal transport system [5]. China has 110,000 km of navigable waterways, whereas India has approximately 14,500 km. The World Bank (WB) estimates that 8.7% of the total freights transported are goods transported over inland waterways in China. The corresponding figures for the United States and European Union (EU) are 8.3% and 7%, respectively. India logs in at a 0.5% freight. In the context of containerized transportation and the possible use of IWT for the same in India, we provide a brief literature review of relevant papers leading to our research study. Some of these papers trace developments in the developed and other parts of the world because they are relevant to similar contexts in India. For example, discusses some failures due to the lack of stakeholder support in the USA [6]. According to this report, key issues were labor charges, resistance to new modes, and the harbor maintenance tax, i.e., selective application fee of 0.125% to water-borne cargoes only. Other barriers have been identified in various studies.

Ro-ro transportation is a viable practice and part of multimodal transportation as it helps to reduce costs. A study in China by Yu et al. [7] opines that customers consider many transportation choices, but the four primary elements are safety issues, convenience, lead time, and cost reduction. Developments in the Chinese economy indicate the importance of waterways. China's entry into the World Trade Organization has also introduced high levels of competition in manufacturing within the country. These and other factors have propelled many firms to move their logistics and manufacturing facilities inland to achieve low production costs. In this context, ro-ro and inland waterway transportation is an alternate way out of the difficulties faced by companies located away from coastal ports [8].

Inland waterways require navigable water to operate. Hence, the lack of availability of this resource is the most important challenge or limitation. The distances and weights moved were affected by the length and size (width, depth, and height). Importantly, it is navigable throughout the year. Thus, the performance of IWT is affected by the quality and quantity of features. For example, the USA can operate some of the world's largest inland water vessels (push barges) despite having a less extensive network than China or

Europe [9]. The maintenance of inland waterways requires funding and has implications for stakeholders. We have also observed various developments in the Indian economy. With the Make in India movement, which is expected to give impetus to manufacturing in India-India as a manufacturing hub-and IWT is a viable alternative to road/rail transport, specifically with multimodal transportation connecting to ports of export.

2.1. IWT in India

The Indian government declared NWs through the NWs Act of 2016 [10] and initiated the development process of 111, in which five are old and 106 are new waterways. The details of all the 111 NWs and the latitude-longitude coordinates of the start and endpoints are given in the above Act. These waterways pass through 24 states and two union territories, and the total length of all these NWs is approximately 20274 km. These inland waterways encounter 138 river systems, related canal systems, estuaries, and creek [11]. The IWAI was set up by the Indian government in 1986 to coordinate and manage the development of NWs (initially five). The scope of control of the IWAI was expanded to cover 111 NWs. Since then, the IWAI conducted feasibility and project studies through consultants who enquired into the potential of each NW. According to reference [12], these studies have mostly been completed. The major findings of these studies are as follows:

a. NWs, having tidal influence connected to sea and traditional waterways, are found to be feasible for navigation.

b. Due to the lack of passenger traffic/cargo, some of the NWs are not feasible despite having navigation potential.

c. Through the study, many barriers are encountered, such as navigational locks, rail and road bridge clearances, and power line passage through the waterways.

d. The projects become unviable financially because of the costs imposed by alterations/modifications to these hurdles.

e. There is an inadequate water depth for navigation due to current water diversions and usage from the rivers.

f. Excessive siltation is a major hurdle for navigational channels in summer due to low discharges.

g. Last- and first-mile connectivity require handling of multiple cargoes as most of them originate in special economic zones and industrial hubs away from inland waterways, which in turn increases the transportation cost.

Based on the recommendations of the above studies, 106 new waterways were categorized into three categories, i.e., A, B, and C, based on specific parameters. Category A represents feasible NWs with cargoes, i.e., 18. Category B includes new waterways with tourism potential, i.e., ferry/cruise, which are 25, and the 63 waterways that are not beneficial either for cruises or cargoes have been categorized in Category C. The development of new waterways through action plans has been developed, where rapid ready cargo, navigational potential, and infrastructure are in place. Finally, a total of 17 channels, including five that existed prior to 2016, were taken up for development. The works on 13 of the new waterways are being carried out under various financial and technical assistance from agencies, such as the WB and national agencies. In addition, through new waterways, no. 73, 100, 83, 85, 91, and 94 significant cargo volumes have been moved through river mouths and tidal waters under the Maharashtra, Gujarat, and Goa Maritime Boards, respectively. Limited government support is required as they are run and developed by private entities. Logistics costs in India are estimated to be approximately 14% of GDP, which is quite high compared to the range of 8-10% in developed countries. If India has to compete with other countries, such as China, logistics costs need to be lowered. As per a report by Aritua [13], the cost per ton-kilometer of different modes of transport is meager and more economical compared to worldwide costs. Manufacturers and shippers can choose lower-cost alternatives while simultaneously reducing the overall logistics cost and improving the competitive strategy. Intending to develop NWs as a key transport intervention and lower logistics costs, the IWAI has implemented many measures to improve the utilization of waterways by manufacturers and shippers.

According to a report by reference [11], the IWAI launched a portal Forum of Cargo-Owners and Logistics-Operators in 2018. This portal provides manufacturers and shippers with access to real-time data on vessel availability. In addition, the IWAI signed a project agreement with the WB for the Jal Marg Vikas Project on the Ganges to augment NW-1 from Varanasi to Haldia. To improve the operability and utilization of waterways, the IWAI has also launched a real-time information system called LADIS. LADIS will disseminate real-time data to manufacturers and shippers at the least available depths. This process will facilitate the day-to-day operations of inland vessels on NWs, thereby avoiding hindrance in service and operation. Apart from preempting problems that may occur during vessel movements, this will improve information sharing and achieve seamless operations on NWs. While the reports indicate that the IWAI has made efforts to overcome the challenges and hindrances by engaging with all stakeholders, including state governments/union territories and concerned central ministries, the most important stakeholder who has been left out is possibly the user/company, which finds the option of IWT as beneficial but is unable to use it to the best advantage due to various factors. For example, the information provided by LADIS may not help in the decision making of customers if the least available depths are not improved to make navigation easy. However, the least available depth in many rivers in India may be sufficient for container movements. The issue of depth is usually less critical because containers are of low density and seldom sink the vessel deep enough in the water for it to be fully loaded without ballast [5].

2.2. Container Transport Through Inland Waterways

Container cargo transport has several inherent advantages. While it reduces the handling cost, it also reduces damage and pilferages and allows an easy modal shift. Cargo owners can also reduce their carbon footprints. In the USA, Europe, and China, the growth in container traffic through IWT is quite impressive. In the USA, inland waterway traffic is substantially high, but there is limited traffic in mainland waterways. On the Mississippi River, this situation is mainly due to the north-south orientation of the river, which does not match with the east-west container movements. Container traffic has stabilized in the Columbia-Snake Waterway from east to west to the sea in Portland. The intermodal transport of containers was more than 60% of the total transport in Portland [5]. Meanwhile, Europe has seen considerable growth in multimodal container transport. There has been a considerable double-digit growth in traffic over the last two decades owing to infrastructure adaption and facilitation of traffic. During the early 1980s, the advantages of cost savings through fully dedicated river container ships were recognized, and new container terminals were built by local interests. An increase in container traffic by IWT has also been facilitated by several features, such as no tonnage limitation, free rates, ICD status, expeditious customs clearance, legislation favoring intermodal transport, and financial measures. In China, shippers have been moving containers on the Yangtze and Pearl River Delta since the 1980s. In the 1970s, the Kowloon wharf was a major container-handling terminal, but Kwai Chung became a dedicated container terminal. In 2002, 2.4 million TEUs of containers were handled in the river trade [5].

2.3. Relevant Factors for Choosing IWT

Freight transportation choices have always been based on many factors. These factors could be objective (e.g., cost and frequency) or subjective (e.g., reliability and service quality), as postulated by D'Este and S. Meyrick [14]. Different authors have identified various factors in their studies, with a commonly occurring set of decision criteria emerging in selecting the mode of transport. These factors include safety, speed, price, lead time, convenience, services, and cargo characteristics [15,16]. Murphy and Hall [17] identified key factors in carrier selection based on an extensive review of research papers published in the 1970s and 1980s. These key factors include freight rates, transit time, reliability, carrier characteristics, cargo requirements, and service during emergencies. Similar factors were reported in Cullinane and Toy [18]. Although these studies did not cover relevant factors, they depend on practical considerations. The actual business and logistics environment and factors for one transportation option may not be the same for the other. In addition, innovations in new modes of transport, digital evolution of logistics and supply chains, and increased outsourcing in manufacturing have increased the choices for shippers; thus, changing the context [19]. From the standpoint of sustainability, IWT is more sustainable than road and rail transport, which are highly congested and polluting. However, IWT has many challenges and limitations. Considering that cargo transportation over inland waterways is substantially cost effective, it is worthwhile to study why India, which has the potential to be a regional superpower and a significant manufacturing and logistics hub, is not making optimum use of IWT.

2.4. Inland Waterways in Europe

One of the early papers [20] brought forward the technical description of inland waterways, the shipping fleet for the same at Europe, volume of cargo and business, legal framework, and inland shipping trends across Europe. The paper also attempted a break-even analysis to explain the need for a sufficient volume of cargoes to make the transport viable. Rohács and Simongáti [21] brought forward the need for sustainable transport development, and the role of inland waterways was envisaged. The study focused on the EU, and the need for inland waterways development for efficient sustainable development was discussed. In another attempt to develop sustainable freight transport, Rogerson et al. [22] proposed a feasible study on waterways along Axios-Morava near the Danube River. Considering the energy efficiency and air quality, inland waterways were better than land and rail alternatives. Rogerson et al. [22] critically analyzed barriers toward the shift to inland waterways in Sweden. The need for policymakers to understand various stakeholders' issues and their concerns to promote inland waterways was brought forward in the findings.

2.5. Research Gap

This study explores possible factors for such failures and non-adoption of the IWT facility in the country, especially within container transportation. Shippers and manufacturers face difficult choices in a complex decision-making environment, and IWT as a preferred method of transport, either as an only alternative or as part of multimodal arrangements, is tricky. Various researchers have proposed different methods for studying decision-making features in such a complex environment. Yu et al. [7] studied the adoption of ro-ro transportation in China using a survey method to obtain views from 338 firms/individuals comprising members from three different stakeholders-manufacturers, shippers, and long-haul drivers. Trivedi et al. [23] studied the barriers to IWT adoption in India by employing the Decision Making Trial and Evaluation Laboratory (DEMATEL) and interpretive structural modeling methods. While the study did not cover containerized cargo, we intend to analyze the adoption of IWT for containerized transport.

Based on the literature review, we identified similar factors and grouped them into a few categories. Then, we processed them through discussions with a few experts through interviews and identified the following factors as relevant for our study.

As mentioned earlier, a study using fuzzy analytic hierarchy process (AHP) has not been attempted till now as per our understanding, and ours will be the first such study of assessment of ports and other related infrastructure. The factors and subfactors were shortlisted based on feedback from experts who were also stakeholders. Experts with a minimum of five years of experience were considered. The shortlisted subfactors are listed in Table 1.

Table 1. *List of factors and subfactors*

Code	Factors	Description
	Economics factors	
EF1	Cost competitiveness	Competitive advantage of inland waterways over other modes of transport in terms of cost
EF2	Transportation lead time	Time taken to prepare the cargo for movement
EF3	Convenience and reliability	availability trustworthy of the transport service
EF4	Capital investment	Investment required to develop the infrastructure
EF5	Pilferage	Loss of cargo or fuel in transit
	Infrastructure factors	
IF1	Safety issues	Accident or losses to vessels and personnel working during the transport operation
IF2	MRO facility shortage	Facility or a location for conducting maintenance of repair works of vessels which is maintenance, repair and overhaul
IF3	Modal integration	Connectivity between Inland waterways and other modes of transport
IF4	Navigational infrastructure	Consists of support for easy navigation such as Digital Geographic information systems and River information systems
IF5	Capacity and efficiency of terminals	Equipment to handle containers with good speed and low costs
IF6	Shortage of vessels	Number of vessels available in the inland waterways for containers
IF7	Infrastructure facilities at shippers' premises for handling containers	Equipment and facilities available to handle container operations like loading, unloading, stuffing, lashing etc.
IF8	Container inventory	Number of empty containers available for domestic and export cargoes
IF9	Container repositioning	Movement of empty containers from the place of unloading to place of loading
	Regulatory factors	
RF1	Government control and jurisdiction	Degree of government restrictions imposed in moving cargoes
RF2	Policy parity	Priority given to inland waterways in comparison to other modes of transport, such as railways and roadways
RF3	Legal issues	Uniform legal rules across all states as the inland waterways move across more than one state
RF4	Customs clearance facilities at loading terminals for exports	Facility to customs clearance at loading terminal and thereby containers are sealed by the customs after stuffing them
	Geographical factors	
GF1	Lack of interlinking	Integration of river basins for the smooth flow of waterways and cargoes
GF2	Inadequate depth in waterways	Constant maintenance of water levels for a good navigation
GF3	Terminal location	Location of terminals across the river basin to load the containers

3. Research Methodology

Multi-criteria decision-making (MCDM) is a widely used tool for ranking (prioritizing) the alternatives based on some conflicting criteria [24]. In the domain of maritime logistics, MCDM techniques are applied by researchers to identify and rank various barriers or factors that influence decision-making processes. Özdemir [25] analyzed the empty container accumulation problem of container ports. In their study, they have provided ranks to various factors identified relating to the empty container accumulation problem using fuzzy DEMATEL and fuzzy TOPSIS tools of MCDM. A decision-making approach for selecting the best solution for the selection of ballast water treatment systems for ships was developed in Özdemir [26]. In their study, the authors used the integrated DEMATEL and ANP methods. In our study, we applied the fuzzy AHP method to provide the weights and rank the factors that influence IWT for container transport. The weights are provided at two levels, factors at one level and subfactors at another level. Fuzzy AHP was used for this study, as making comparisons through linguistic terms is relatively easy for respondents. As the network decision-making considered in this study is not very complex (it involves two levels) and does not include several criteria, fuzzy AHP is the most appropriate MCDM tool for this study. Our study is based on a sample of nine respondents from different stakeholder groups and uses a fuzzy AHP methodology.

3.1. Fuzzy AHP Methodology

Among the many MCDM tools, the AHP method developed Saaty [27] is widely used by researchers to provide the weights to criteria and rank alternatives. The AHP analysis is based on preference scores provided by decision-makers (or experts) and, hence, often involves time vagueness. To deal with such vagueness due to human judgments, a fuzzy AHP was proposed by Buckley [28]. Fuzzy AHP involves the concept of fuzzy logic with the pairwise comparison-based MCDM tool AHP. The weights for factors and subfactors in this study are calculated using the FuzzyAHP package in R software [29]. The "FuzzyAHP" package follows the methodology provided by Krejčí et al. [30] for calculating the weights of factors. The inputs from decision-makers for the preference matrix are collected in linguistic terms), which makes the data collection process practical. The fuzzy numbers corresponding to each linguistic term are used for the computation of weights, as given in Table 1. Fuzzy triangular numbers are used to denote linguistic preferences.

The general fuzzy triangular number is denoted by $\widetilde{A}(x)=(l,m,u)$, with the membership function

$$\mu_{\widetilde{A}(x)}=\begin{cases}0, & x<l\\ \dfrac{x-l}{m-l}, & l\le x\le m\\ \dfrac{u-x}{u-m}, & m\le x\le u\\ 0, & x>u\end{cases} \tag{1}$$

The membership function $\mu_{\widetilde{A}(x)}$ can graphically be presented as Figure 1.

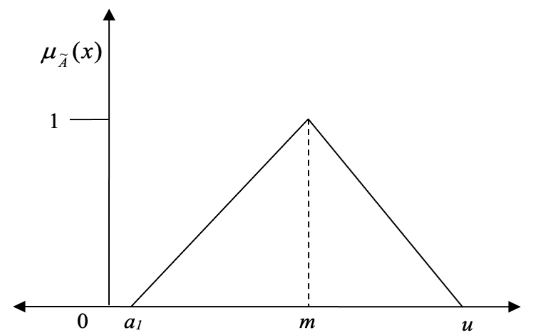

Figure 1. *Membership function for triangular fuzzy numbers*

The stepwise procedure for applying fuzzy AHP is as follows:

Step 1: Construct a fuzzy pairwise comparison matrix:

Based on the responses collected from the experts, fuzzy pairwise comparison matrices were constructed as follows:

$$\widetilde{D}=\begin{bmatrix}\widetilde{a}_{11} & \widetilde{a}_{12} & \cdots & \widetilde{a}_{1n}\\ \widetilde{a}_{21} & \widetilde{a}_{22} & \cdots & \widetilde{a}_{2n}\\ \vdots & \vdots & \ddots & \vdots\\ \widetilde{a}_{n1} & \widetilde{a}_{n2} & \cdots & \widetilde{a}_{nn}\end{bmatrix} \tag{2}$$

where $\widetilde{a}_{ij}$ represents the preference of the i^{th} criteria over the criteria provided by the decision-maker.

If the triangular fuzzy number for j^{th} is $\widetilde{a}_{ij}$ is (a^l, a^m, a^u), then for $\widetilde{a}_{ji}$, the triangular fuzzy number will be $\left(\frac{1}{a^u},\frac{1}{a^m},\frac{1}{a^l}\right)$.

Step 2: Compute the fuzzy geometric mean for the criteria:

Using Equation (3), the geometric mean of the fuzzy pairwise preference matrix was calculated for each criterion.

$$\tilde{r}_i = \left(\prod_{j=1}^{n} \tilde{a}_{ij} \right)^{\frac{1}{n}}, \quad \forall i = 1, 2, \ldots, n \tag{3}$$

Step 3: Compute fuzzy weights for the criteria:

The fuzzy weights $\tilde{w}_i$ for each criterion i were calculated using Equation (4).

$$\tilde{w}_i = \tilde{r}_i \times \left(\sum_{i=1}^{n} \tilde{r}_i \right)^{-1} \tag{4}$$

Step 4: Defuzzification of fuzzy weights:

Using the center of area approach represented by Equation (5), we obtain the equivalent crisp weights (w_i) for each of the fuzzy weights, i.e., $\tilde{w}_i = (w_i^l, w_i^m, w_i^u)$.

$$w_i = \left[\left(w_i^u - w_i^l \right) + \left(w_i^m - w_i^l \right) \right] / 3 + w_i^l \tag{5}$$

Step 5: Normalization of crisp weights:

Using Equation (6), the normalized weight (N_i) for each criterion is obtained:

$$N_i = \frac{w_i}{\sum_i w_i} \tag{6}$$

3.2. Data Collection

A well-structured questionnaire was circulated to the group of nine experts in inland waterways in India, who are shippers, operators, and personnel from India's inland waterways' authority. Nine members agreed to respond to a questionnaire based on telephonic requests. The respondents consisted of personnel working with three members working with shippers, four working with inland waterway operators, and two working with the inland waterway's authority. All the respondents worked at the managerial level with a minimum work experience of five years in the inland waterway's domain. The responses were limited due to the pandemic situation in the country, and based on the domain knowledge of the respondents, nine were assumed to be adequate. Brief details of the respondents are given in Table 2. In addition, the scale of importance for the fuzzy AHP analysis are detailed in Table 3.

The responses were used for further analyses. The shortlisted factors and subfactors used for the analysis are shown in Figure 2.

Table 2. *Details of the respondents*

Number of respondents	Respondent category	Experience and role
3	Shippers-Customers using inland waterway services for transportation	Five to 9 years of experience in export/import of cargoes
4	Inland waterway operators-Personnel working at the managerial level with operators in inland waterways	Five to seven years of experience in operating vessels in inland waterways
2	Inland Waterways Authority of India-Personnel working as a consultant or expert in the traffic and logistics department of IWAI	Five to 8 years of experience in the domain
IWAI: Inland Waterways Authority of India		

Table 3. *Scale of importance for the fuzzy AHP analysis*

Linguistic scale	Equivalent crisp score	Equivalent triangular fuzzy scale
Equally important	1	(1, 1, 1)
Weakly important	3	(2, 3, 4)
Fairly important	5	(4, 5, 6)
Strongly important	7	(6, 7, 8)
Absolutely important	9	(9, 9, 9)
Intermittent values	2	(1, 2, 3)
	4	(3, 4, 5)
	6	(5, 6, 7)

4. Results and Analysis

Table 4 and Figure 3 show that infrastructure factors are the highest ranked, followed by economic factors (EFs), geographical factors, and regulatory factors (RFs). This result brings forth the prominence of infrastructure as a major element affecting container shipping. EFs are the second most significant factor affecting waterways. The fuzzy ranking of the subfactors is discussed below, and their importance is discussed.

Among the subfactors of EFs, transportation lead time EF2, capital investment EF4, and convenience and reliability EF3 have emerged as the top three, respectively, as shown in Table 5 and Figure 4.

The container inventory IF8 remains a major concern among IFs. The container repositioning IF9, capacity, and efficiency of terminals IF5 follow, as shown in Table 6 and Figure 5.

The need for customs clearance facilities at loading terminals for exports RF4 is a major subfactor, followed by legal issues RF3 among the RFs, as shown in Table 7 and Figure 6.

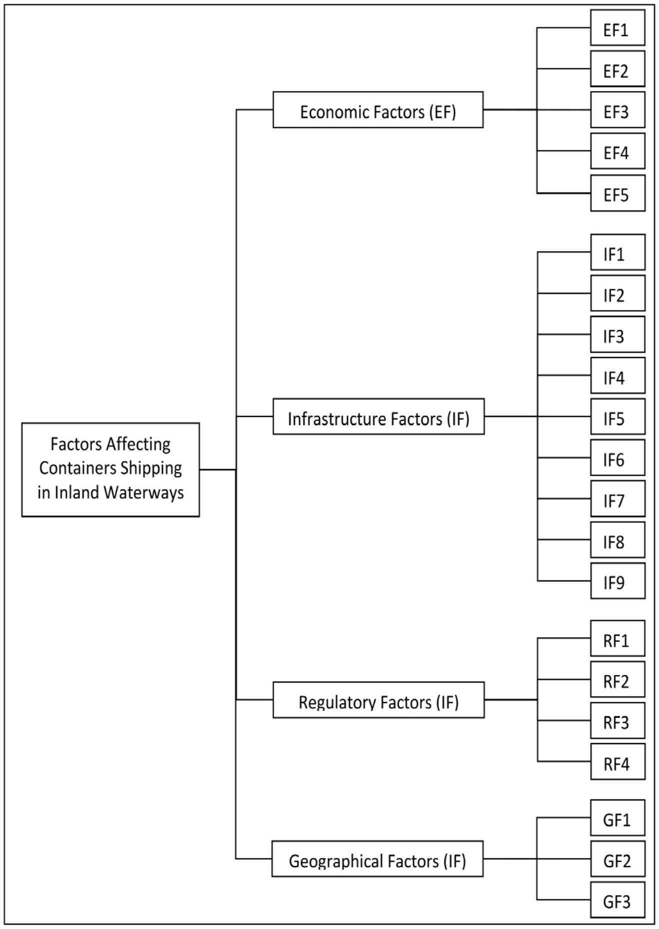

***Figure 2.** Hierarchy of factors affecting inland waterway shipment*

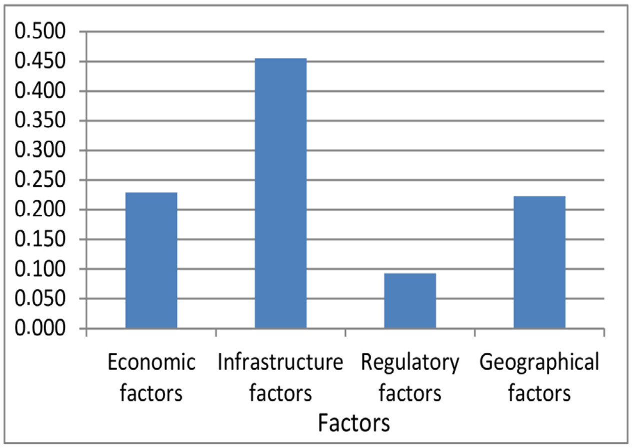

***Figure 3.** Relative importance of factors*

***Table 4.** Fuzzy and equivalent crisp weights of factors*

Factors	Fuzzy weight for factors	Crisp weight for factors	Normalized weight	Rank
Economic factors	(0.204, 0.238, 0.261)	0.234	0.229	2
Infrastructure factors	(0.426, 0.462, 0.503)	0.464	0.455	1
Regulatory factors	(0.066, 0.097, 0.123)	0.095	0.093	4
Geographical factors	(0.183, 0.227, 0.272)	0.227	0.223	3

***Table 5.** Weights and rank of the subfactors of economic factors*

Subfactors	Fuzzy weight (local) for subfactors	Crisp weight (local) for subfactors	Normalized weight	Rank
EF1	(0.089, 0.127, 0.166)	0.127	0.127	4
EF2	(0.354, 0.410, 0.465)	0.41	0.409	1
EF3	(0.113, 0.169, 0.222)	0.168	0.167	3
EF4	(0.223, 0.253, 0.286)	0.254	0.253	2
EF5	(0.033, 0.042, 0.058)	0.044	0.044	5

Inadequate depth in waterways GF2 due to constant silting, rains, and irrigation is a significant subfactor among the GFs, followed by a lack of interlinking of waterways, as shown in Table 8 and Figure 7.

As shown in Table 9 and Figure 8, the inadequate depth in waterways GF2 remains a major subfactor from the global ranking. The next two subfactors are container inventory IF8 and container repositioning IF9, which are related to each other and are due to a shortage of empty containers for export and domestic cargo movements. Finally, transportation lead time EF2 and the capacity and efficiency of terminals IF5 remain globally ranked at 4 and 5, respectively.

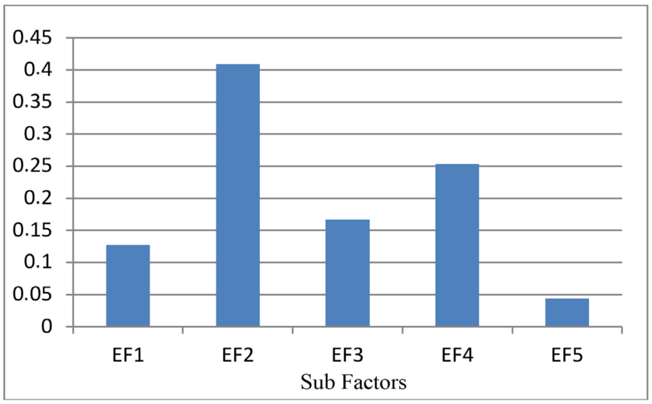

Figure 4. *Relative importance of subfactors of economic factors*

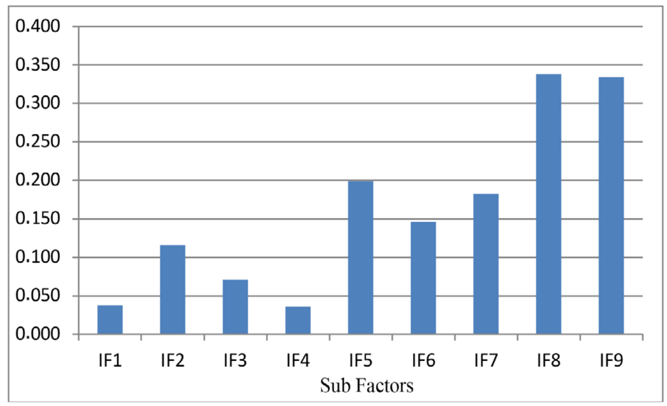

Figure 5. *Relative importance of subfactors of infrastructure factors*

Table 6. *Weights and rank of the subfactors of infrastructure factors*

Subfactors	Fuzzy weight (Local) for subfactors	Crisp weight (local) for subfactors	Normalized weight	Rank
IF1	(0.020, 0.027, 0.038)	0.028	0.038	8
IF2	(0.061, 0.087, 0.109)	0.086	0.116	6
IF3	(0.042, 0.053, 0.066)	0.053	0.071	7
IF4	(0.016, 0.027, 0.038)	0.027	0.036	9
IF5	(0.122, 0.150, 0.172)	0.148	0.199	3
IF6	(0.071, 0.109, 0.146)	0.108	0.146	5
IF7	(0.098, 0.135, 0.172)	0.135	0.182	4
IF8	(0.198, 0.254, 0.301)	0.251	0.338	1
IF9	(0.209, 0.246, 0.288)	0.248	0.334	2

Table 7. *Weights and rank of the subfactors of regulatory factors*

Subfactors	Fuzzy weight (local) for subfactors	Crisp weight (local) for subfactors	Normalized weight	Rank
RF1	(0.165, 0.211, 0.252)	0.209	0.202	3
RF2	(0.076, 0.115, 0.157)	0.116	0.112	4
RF3	(0.228, 0.301, 0.384)	0.304	0.294	2
RF4	(0.316, 0.402, 0.495)	0.404	0.391	1

Table 8. *Weights and ranks of the subfactors of geographical factors*

Subfactors	Fuzzy weight (local) for subfactors	Crisp weight (local) for subfactors	Normalized weight	Rank
GF1	(0.095, 0.163, 0.220)	0.159	0.158	2
GF2	(0.582, 0.693, 0.816)	0.697	0.693	1
GF3	(0.101, 0.151, 0.196)	0.149	0.148	3

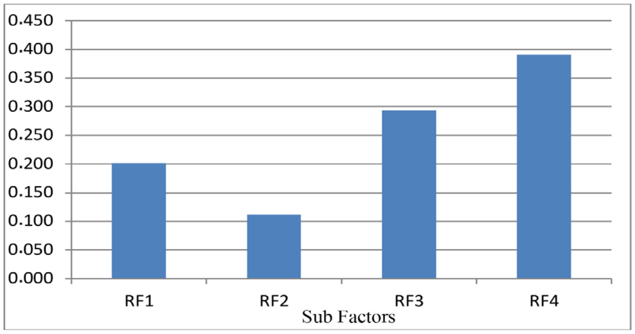

Figure 6. *Relative importance of subfactors of regulatory factors*

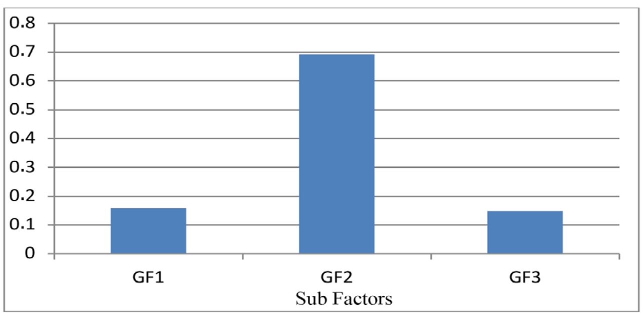

Figure 7. *Relative importance of subfactors of geographical factors*

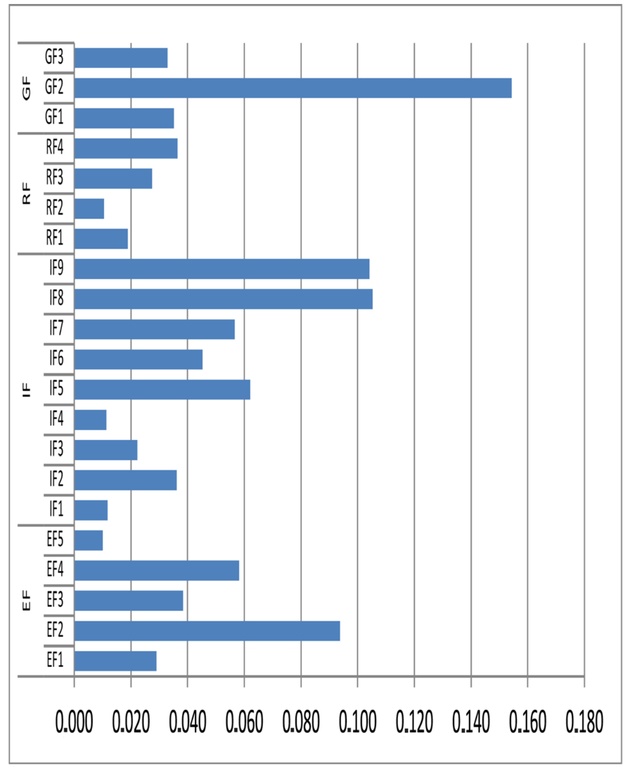

Figure 8. *Relative importance of all subfactors*

Table 9. *Global weights and ranking of subfactors*

Factors	Subfactors	Global weight	Rank
Economic factors (EFs)	EF1	0.029	14
	EF2	0.094	4
	EF3	0.038	9
	EF4	0.058	6
	EF5	0.010	21
Infrastructure factors (IFs)	IF1	0.012	18
	IF2	0.036	11
	IF3	0.022	16
	IF4	0.011	19
	IF5	0.062	5
	IF6	0.045	8
	IF7	0.057	7
	IF8	0.105	2
	IF9	0.104	3
Regulatory factors (RFs)	RF1	0.019	17
	RF2	0.010	20
	RF3	0.027	15
	RF4	0.036	10
Geographical factors (GFs)	GF1	0.035	12
	GF2	0.154	1
	GF3	0.033	13

5. Conclusion

Our study, which uses the AHP method, indicates the lacunae in India's ports and other waterway infrastructure. The indications reinforce our general or specific perception about the shortcomings. To this extent, the study is useful as a reinforcer element in our understanding. The findings from this study suggest that an inadequate depth of rivers is a major factor hindering container shipping. In previous studies, this situation was also evident for general bulk cargo movements across inland waterways. Hence, there is a need for dredging and other related measures to maintain sufficient water levels. Moreover, container inventory and repositioning of containers are major subfactors that need to be addressed. There is a need for two types of containers, first for domestic movements and second for cargo export. Therefore, comprehensive support and policy-driven incentives are required to drive the domestic manufacturing of containers, rather than relying on overseas manufacturers. Imported containers have a constraint of exporting within six months of entry into the country. They must also be stimulated to use inland waterways for inward movements. The capacity and efficiency of terminals need to be improved with good capital investment through the public-private partnership mode, providing better utilization of capital and efficient waterway management. The central government has tried to bring inland waterways and coastal shipping at par with railways and roadways through the SagarMala Project. This project has attempted to integrate coastal shipping, inland waterways, roadways, and railways through an investment of approximately 7 billion USD. Inland waterways also need to be considered an option to reduce the carbon footprint in India. Roadways are more flexible owing to the last-mile connectivity advantage, while inland waterways are the best option to reduce carbon emissions. The reduction of road accidents by high traffic volumes on highways and low pollution levels can be reduced by providing subsidies in freight, directly or indirectly, until the country reaches sustainable traffic in waterways. Although the Indian government has identified the challenges, we need to understand whether sufficient policy initiatives are being made to tackle them. In this context, a study of the major port initiatives and their review is needed to understand how far we can achieve the orchestrated vision. Moreover, as identified in the port sector, the dual-institution structure has led to the development of major and nonmajor ports as separate, unconnected entities. Further policy studies need to be undertaken if this drawback can be removed by bringing all ports under one governmental jurisdiction. Bilateral agreements with neighboring countries, such as Nepal, Bangladesh, Bhutan, and Myanmar, with joint investments in infrastructure are needed to promote low-carbon emission and economical IWT could boost the GDP and economy across the region. The adoption of key performance indicators in inland waterways and linking them through various incentives could help us monitor and achieve good milestones in terms of traffic and profits. The adoption of low-cost and effective dredging from European experiences, maintenance of a minimum depth of water levels by installing effective lock system for good navigation, and accommodation of wide ships and multiple vessels could be useful.

Authorship Contributions

Concept design: B.R. Totakura, Data Collection or Processing: B.R. Totakura, A. PJ, Analysis or Interpretation: S.A. Jalil, Literature Review: N. Narasinganallur, Writing, Reviewing and Editing: B.R. Totakura, N. Narasinganallur, S.A. Jalil, A. PJ.

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