

Cost–Time–Demand Trade-offs in Air and Sea Transit from Chennai to Rotterdam

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ABSTRACT

The objective of the Study on Cost-Time-Trade-offs Between Air and Sea Freight Transportation from the Port of Chennai, India to the Port of Rotterdam, Netherlands is to determine the methodology incorporated by businesses when deciding between utilizing air versus sea freight. These decisions are influenced by numerous variables including the cost of transportation, transit time, and customer demand. In an international logistics perspective, how a company chooses to transport goods will ultimately affect the overall efficiency of their supply chain, the satisfaction of their customers, and the company's delivery performance. As one of the largest commercial routes connecting Indian products to European markets, selecting the appropriate mode of transportation has important implications for the company's operation. The main objective of the study is to analyse how logistics companies balance transportation cost, delivery speed, and shipment urgency while choosing between air and sea transport. The research is based on primary data collected from 60 respondents working in logistics, freight forwarding, shipping, and supply chain management through a structured questionnaire. Convenience sampling was used for data collection. The IBM SPSS program was applied to analyse the following methods: descriptive statistics, percentage analysis, weighted average ranking, chi-square testing, correlation analysis, regression analysis, and ANOVA. Based on this research, results show that air transport is preferred to deliver items that need to be shipped urgently or quickly because it takes less time for delivery and can rely on the reliability of the delivery itself. In contrast, sea transport will usually be the preferred mode of shipment for normal and bulk items due to its lower cost than air transport. In terms of influence on transportation decisions, cost is by far the most important factor, followed by urgency of demand and time in transit. Ultimately, the research suggests that to improve both logistics performance and customer satisfaction, there must be a strategic balance between the cost of transportation, how quickly the transportation can be completed, and consumer demand for products when planning for transportation services between Chennai, India and Rotterdam, Netherlands.

Keywords: Air Transport, Sea Transport, Cost Efficiency, Transit Time, Demand Urgency, Logistics Decision-Making.

Introduction

Transportation is integral to the transportation logistics industry as well as the supply-chain management industry because both depend heavily on international trade routes for success through delivery on time, costs associated with the delivery and the overall satisfaction of the customer. Goods

moving from Rotterdam in Europe to Chennai in India represent a significant link within the international trade between the two continents. Rotterdam is one of the largest ports in Europe and serves as a critical entry for goods coming into the European market while Chennai is one of the principal export hubs in India. Therefore, choosing the mode(s) of shipping from Rotterdam to Chennai represents a critical strategic decision for logistics companies, freight forwarders and exporters. Each of the two modes of transportation (air and ocean) has unique advantages and disadvantages. Air freight is the fastest and most reliable shipping option for high-value and time-sensitive shipments; however, it is also much more expensive than other methods. Conversely, ocean freight is the best option for large-scale shipping due to its lower cost but longer transit times and its susceptibility to delays caused by congestion at ports. When selecting the best mode of transportation, companies must continually compare the trade-offs between transportation costs, transit times, and customer's expectations. Companies may choose to use air freight because of the immediacy of the product's arrival even though it is more expensive than shipping by ocean. However, ocean freight would be the best option for companies that are shipping frequently, where controlling costs is a primary concern. This decision-making process affects the company's ability to manage the four key elements that contribute directly to inventory planning, customer service, operations, and profitability. The study's primary objective is to identify the way logistics experts solve these cost/time/demand trade-off problems related to shipments between Chennai and Rotterdam. The study will identify the most important variables that affect transportation decisions and analyse how businesses use air and marine modes of transportation in various business contexts. The study uses statistical methods such as Chi-Square, Correlation, Regression, and ANOVA for further analytical support of the findings. This study is important because it shows how choosing a method of transportation has both strategic and operational implications on supply chain performance. By examining how companies respond in the real world, this research will provide logistics companies and firms that transport freight internationally between India and Europe with useful insights.

Problem Identification

One of the major challenges faced by international logistics companies is choosing an appropriate mode of transport for goods that are imported or exported. Companies that are moving goods between Chennai, India and Rotterdam, Netherlands will choose to transport their products via either air or sea depending on various factors including cost, transit time, urgency (i.e., if it has to be delivered quickly), customer demand, and reliability of service. Each mode of transportation will present its own advantages, but if someone were to select the incorrect mode, they face additional logistical costs, delayed delivery of goods to customers, unhappy customers at the point of sale, and a decrease in overall level of operational efficiency. Generally speaking, sea freight is the preferred mode of transport for frequent shipment or large quantities of product because of its lower cost and higher volume capacity. However, if the business operations or customer commitments require shipments to be delivered quickly, the length of time it takes to transport goods via sea freight, the potential for congestion at ports of entry, and delays in delivery can cause significant impacts in both business operations and customer commitments. On the other hand, air transport provides faster delivery and higher reliability for urgent and high-value shipments, but the significantly higher transportation cost limits its regular use.

Although air transport is a faster and more reliable option for transporting high-value or urgent goods, the high cost of transportation limits its frequent usage. When selecting a mode of transport, many businesses find it challenging to balance the trade-offs between time, demand, and transportation cost. Companies must often rely on expensive airfreight because of the urgency of their customer's request for products, and a lack of adequate planning can lead to spending a lot of money on last-minute transportation. On the other hand, selecting sea freight merely to minimize cost when delivery is urgent can raise the likelihood of delivery problems. The problem becomes even more important when you're considering the Chennai-to-Rotterdam transportation route - this important international trade route connects Indian suppliers with European customers but to date there has been literature that looks explicitly at how logistics firms make transportation decisions both descriptive information

Therefore, the problem identified in this study is the need to understand how organizations balance transportation cost, transit time, and customer demand while selecting between air and sea transport from Chennai to Rotterdam, and which factors have the strongest influence on transportation mode selection.

Review of Literature

Christopher (2016) explained that transportation mode selection is one of the most important strategic decisions in supply chain management because it directly affects delivery performance, logistics cost, and customer satisfaction. The study highlighted that air transport is preferred for urgent and high-value shipments due to speed and reliability, while sea transport is suitable for bulk cargo because of lower cost and larger carrying capacity. Chopra and Meindl (2019) stated that transportation decisions in global logistics depend mainly on balancing cost efficiency and responsiveness. Their study emphasized that organizations often use sea freight for regular shipments and shift to air freight when customer demand becomes urgent. The researchers concluded that transportation planning must align with business strategy and customer service expectations. Johnson and Lee (2021) conducted a study on multimodal transportation strategies and found that combining air and sea freight improves operational flexibility. The study explained that businesses use sea transport for standard shipments and air transport for urgent deliveries, helping them reduce cost while maintaining service quality and customer satisfaction. Ahmed and Rahman (2020) examined freight cost management in export logistics and found that transportation expenses strongly influence customer service performance. Their study showed that poor transportation planning increases delivery delays and customer complaints, while proper freight cost control improves logistics efficiency and business performance.

Brown (2022) studied the impact of port congestion on international sea freight operations and found that delays at major ports significantly affect inventory planning, customer commitments, and operational efficiency. The study concluded that many organizations shift urgent shipments to air transport during severe sea freight delays despite higher transportation cost. Wilson and Carter (2021) researched customer expectations and delivery speed in international supply chains and found that increasing customer demand for faster delivery pushes organizations to prefer air transport for urgent and high-value shipments. However, sea transport remains the economical option for less urgent deliveries. Fernandez (2023) explained that poor inventory forecasting increases emergency shipments and forces organizations to depend on expensive air freight services. Better inventory planning allows companies to use sea transport more effectively and reduce urgent deliveries, improving cost control and logistics performance. IATA Report (2023) highlighted that air cargo supports high-value industries such as pharmaceuticals, electronics, and urgent shipments where delivery speed and reliability are critical. Although air freight is expensive, it remains essential for time-sensitive cargo movement in global trade. IMO Report (2022) stated that sea transport handles the majority of global trade volume because of lower freight cost and high cargo capacity. However, long most of transport.

Research Gap

Most of the previous studies on transportation mode selection mainly focus on general comparisons between air transport and sea transport based on cost, speed, and service efficiency. Many researchers have written about how companies choose air or ocean transportation based on many different attributes such as the value of the product, the need for delivery and how quickly the goods need to be transported. Most of these studies have been general and have not focused on a specific lane. The Chennai to Rotterdam route is a very important link for moving goods between India and Europe and has not been adequately studied. The existing studies do not explain in detail how companies manage to meet customers' demands, transit times and transportation costs for this route. Additionally, many of the previously conducted studies utilized descriptive analysis only and did not include complex statistical procedures such as chi-square, correlation, regression, or ANOVA in order to measure the actual relationships between the various variables that influence transportation decisions. There is also limited primary-data-based research involving logistics professionals directly engaged in freight forwarding and shipment planning. Therefore, this study aims to fill this gap by focusing specifically on the Chennai to Rotterdam route and analysing the cost–time–demand trade-offs using both descriptive and inferential statistical methods for better practical understanding.

Objectives of the Study

- To analyse the total cost and time of transport between Chennai and Rotterdam for both air and sea transport and assess the demand level.
- To compare the difference in cost between air and sea transport
- To analyse the difference between the transit time of air and sea transport
- To study the effects of fluctuating demand on transportation decisions

- To identify the factors that affect the selection of mode of transport
- To provide recommendations for optimising transportation decisions

Hypothesis Testing

By using hypothesis testing, researchers can evaluate if their assumptions about the research are supported by the data collected during a study. This provides researchers with greater confidence in their concluding statements regarding their research as well as enables them to determine whether there is a statistically significant relationship between variables being tested or measured.

The following hypotheses were framed for the study:

- H1:** Demand urgency has a significant impact on the use of air transport.
H2: Transportation cost has a significant impact on the selection of sea transport.
H3: Transit time has a significant impact on transport mode selection.
H4: Customer demand has a significant impact on transportation decision-making.
H5: Years of experience significantly influence transportation decision preferences.

These hypotheses were tested using statistical tools such as Chi-Square Test, Correlation Analysis, Regression Analysis, and ANOVA through IBM SPSS Software.

Research Methodology

This research will investigate how the cost and time required to deliver goods to Rotterdam may influence the mode of transportation used by companies in Chennai, India. A descriptive and an analytical approach to the study is utilized; a structured questionnaire was developed to acquire primary data from 60 supply chain and logistic professionals. All 60 respondents (their selection based on convenience sampling - i.e., their accessibility and availability) responded to the same set of questions (multiple choice; yes/no; rank; scale) asking about client demand; transit time; transportation cost; and urgency of the client demand, which were then analyzed using SPSS (IBM Corp Version 24.0) as follows: descriptive analysis (percentage and comparative tables) and inferential statistics (Chi-Square, Correlation, Regression, and ANOVA). The results were found to be statistically reliable, and as a result, numerous conclusions are documented in the study.

Discussion

The collected primary data was analysed using IBM SPSS Software to examine the relationship between transportation cost, transit time, demand urgency, and transport mode selection between Chennai and Rotterdam. The statistical tools used for analysis include Chi-Square Test, Correlation Analysis, Regression Analysis, and ANOVA. These tools helped in validating the hypotheses and identifying the significance of major transportation decision factors.

Chi-Square Test

Chi-Square test is used to examine whether there is a significant relationship between two categorical variables. It helps in identifying whether the observed relationship occurs due to actual association or by chance. In this study, Chi-Square test is used to analyse the relationship between demand urgency and the use of air transport.

Chi-Square Test

Particulars	Value
Pearson Chi-Square	2.811
Degrees of Freedom (df)	3
Significance Value (Sig.)	0.422
Likelihood Ratio	2.852
Linear-by-Linear Association	2.218
No. of Valid Cases	59

The Chi-Square test shows that the significance value is 0.422, which is greater than 0.05. This indicates that there is no statistically significant relationship between demand urgency and the use of air transport. Therefore, the null hypothesis is accepted, and the variables are considered independent.

Correlation Matrix

Correlation analysis is used to identify the strength and direction of the relationship between important variables affecting transportation decisions. It helps in understanding whether the variables move together positively or negatively and how strongly they influence each other. The study examines the relationship between cost level of air transport, cost level of sea transport, importance of cost in decisions, importance of transit time, frequency of urgent shipment demand, and willingness to pay more for faster delivery.

Pearson Correlation Matrix

Variable	Q11 Cost Level of Air Transport	Q12 Cost Level of Sea Transport	Q13 Importance of Cost in Decisions	Q16 Importance of Transit Time	Q23 Frequency of Urgent Shipment Demand	Q27 Willing to Pay More for Faster Delivery
Q11 Cost Level of Air Transport	1.000	—	—	—	—	—
Q12 Cost Level of Sea Transport	-0.155	1.000	—	—	—	—
Q13 Importance of Cost in Decisions	0.211	0.018	1.000	—	—	—
Q16 Importance of Transit Time	0.001	-0.038	-0.026	1.000	—	—
Q23 Frequency of Urgent Shipment Demand	-0.007	0.448**	-0.085	0.013	1.000	—
Q27 Willing to Pay More for Faster Delivery	-0.059	0.051	0.255	0.037	0.145	1.000

The correlation matrix shows a moderate positive relationship between the cost level of sea transport and the frequency of urgent shipment demand (0.448), which is statistically significant. This indicates that transportation cost and shipment urgency are closely connected in logistics decision-making. Most other variables show weak relationships, suggesting that transportation decisions depend on multiple practical factors rather than a single variable.

Regression Analysis

Regression analysis is used to examine the impact of independent variables on a dependent variable. It helps in identifying how strongly factors such as cost, transit time, and demand urgency influence transportation decisions.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error
1	0.308	0.095	0.009	0.728

ANOVA (Regression Model)

Source	Sum of Squares	df	Mean Square	F Value	Sig.
Regression	2.930	5	0.586	1.107	0.368
Residual	28.053	53	0.529		
Total	30.983	58			

Coefficients

Variable	B	Std. Error	Beta	t	Sig.
(Constant)	2.022	0.511	—	3.961	<0.001
Cost Level of Sea Transport	-0.175	0.122	-0.210	-1.433	0.158
Importance of Cost in Decisions	0.245	0.129	0.260	1.904	0.062
Importance of Transit Time	0.003	0.125	0.003	0.024	0.981
Frequency of Urgent Shipment Demand	0.092	0.107	0.129	0.862	0.393
Willingness to Pay More for Faster Delivery	-0.109	0.112	-0.133	-0.970	0.336

The regression analysis shows that the model significance value is 0.368, which is greater than 0.05, indicating that the model is not statistically significant. This means that the selected independent variables do not significantly predict the cost level of air transport. Although some variables show minor influence, none of them have a strong statistically significant impact on the dependent variable.

One-Way Anova

One-Way ANOVA is used to examine whether there is a significant difference among respondent groups based on demographic factors such as years of experience. It helps in identifying whether employee characteristics influence transportation decision-making and perceptions regarding air and sea transport.

In this study, ANOVA is used to test whether years of experience significantly affect views on transportation cost, transit time, demand urgency, and willingness to pay for faster delivery.

One-Way ANOVA

Variable	Sum of Squares	df	Mean Square	F Value	Sig.	Result
Cost Level of Air Transport	4.416	3	1.472	3.048	0.036	Significant
Cost Level of Sea Transport	2.036	3	0.679	0.875	0.459	Not Significant
Importance of Cost in Decisions	3.597	3	1.199	2.111	0.109	Not Significant
Importance of Transit Time	3.616	3	1.205	2.186	0.100	Not Significant
Frequency of Urgent Shipment Demand	6.867	3	2.289	2.347	0.083	Not Significant
Willingness to Pay More for Faster Delivery	4.486	3	1.495	1.949	0.132	Not Significant

The ANOVA results show that only the cost level of air transport has a significance value less than 0.05, indicating a statistically significant difference among respondents based on years of experience. This means that work experience influences how respondents perceive the cost of air transport. The remaining variables show no significant difference among groups.

Suggestion

- Organizations should adopt a balanced transportation strategy by using both air transport and sea transport based on shipment urgency, cargo type, and customer requirements instead of depending on a single mode.
- Sea transport should be preferred for regular and bulk shipments where cost control is important and delivery deadlines are flexible.
- Air transport should be used mainly for urgent, high-value, and time-sensitive shipments where faster delivery directly improves customer satisfaction and business performance.
- Companies should improve demand forecasting and shipment planning to reduce last-minute urgent shipments that increase dependence on costly air freight.
- Proper inventory planning should be maintained to avoid delays caused by sudden demand fluctuations and poor transportation scheduling.
- Backup logistics planning should be developed to manage sea transport delays, port congestion, and operational disruptions without affecting customer commitments.
- Organizations should regularly compare freight costs and transit performance between air and sea transport to make better operational decisions.
- Technology such as shipment tracking systems and transport planning software should be used to improve visibility, coordination, and delivery reliability.

Conclusion

According to the study "Cost-Time-Demand Trade-offs for Air and Sea Transit from Chennai to Rotterdam", choosing a transportation mode when dealing with international logistics is one of the most important decisions made in international logistics management today. Both sea and air transportation

are vital for international commerce; however, the potential benefits of each mode vary based on the actual shipment requirements, customer demands, and company priorities. In most cases, sea transportation will be the preferred mode for normal and larger shipments because of its greater cargo capacity and lower transportation costs.

As such, if cost containment is your main objective and the need for timely delivery is not urgent, sea transportation is most likely your transportation method of choice. Alternatively, air transportation is frequently chosen for high-value, urgent, and time-sensitive shipments because of its faster transportation times and better delivery reliability. There are three primary things that affect transportation solutions according to the survey: client demand, cost and delivery time.

Many companies were compelled to use higher cost, quicker transportation methods in order to be able to respond quickly to unforeseen fluctuations in demand or urgent delivery commitments and customer service levels. In order to remain profitable and operationally efficient, companies must try to control their logistics costs at the same time. Use of statistical analysis including Chi-Square, Correlation, Regression and ANOVA have also corroborated these findings. Transportation options are based on several different criteria such as delivery speed, urgency, practicality of doing business and the cost of transportation.

Accordingly, a flexible and strategic transportation planning approach that can accommodate both air transportation as well as marine transportation based on shipment requirements and operational priorities will be necessary for the success of transportation planning for shipments from Chennai to Rotterdam. Organizations that effectively manage these cost–time–demand trade-offs can achieve better customer satisfaction, stronger supply chain performance, and long-term business success.

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