TOWARDS A BOTTOM-UP COST MODEL FRAMEWORK FOR FREIGHT TRANSPORTATION IN INDIA: ROAD AND RAIL PERSPECTIVES

Thesis Submitted
in partial fulfillment of the requirements for the degree of

MASTER OF TECHNOLOGY
in
Industrial Engineering And Management

by

Rajender
(23/IEM/06)

Under the Supervision of

Dr. Mohd Shuaib
Assistant Professor, Department of Mechanical Engineering
Delhi Technological University

To the
Department of Mechanical Engineering
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Shahbad Daulatpur, Main Bawana Road, Delhi-110042, India
May, 2025

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2. Roll No: **23/IEM/06**
3. Thesis title:
   Towards A Bottom-Up Cost model Framework for Freight Transportation in India: Road and Rail Perspectives.
4. Degree for which the thesis is submitted: M. Tech
5. Faculty of the University to which the thesis is submitted : Dr. Mohd. Shuaib
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IEM501 : Data Analytics IEM503 : Production & Operation Management IEM5205 : Principles of Managment IEM5305 : Total Quality Management IEM5407 : Product Design & Development

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			4.00	4.00	2.00	3.00	4.00				
1	23/IEM/01	RAVI RANJAN	F	F	A+	O	A+	6.46	9	...	IEM501
2	23/IEM/02	AATIF AMEER	O	B+	A+	O	O	9.18	17	9.176	
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4	23/IEM/04	REDDI DUSHYANTH VENKATA SAI KRISHNA	A+	B+	A+	A	A	8.12	17	8.118	
5	23/IEM/05	DIVYANSH	C	C	A	C	B+	5.82	17	5.824	
6	23/IEM/06	RAJENDER	A+	B	A	A	A	7.76	17	7.765	
7	23/IEM/07	PIYUSH KUMAR	A+	B	A+	B	A	7.53	17	7.529	
8	23/IEM/08	ISHAN KOTNALA	C	F	B	C	B	4.18	13	...	IEM503
9	23/IEM/09	LOKESH KUMAR	A+	B+	A+	B+	A	7.94	17	7.941	
10	23/IEM/10	DHRUV SHANKAR SAXENA	A+	A	O	O	A+	9.06	17	9.059	
11	23/IEM/11	SHISHIR	A+	A+	A+	A+	A+	9	17	9	
12	23/IEM/12	MORIE MEYER KOUNA FERRAND	C	P	B+	B	B+	5.65	17	5.647	
13	23/IEM/13	FREDRICK KABWE	C	B	A	B+	B+	6.41	17	6.412	

IEM501 : Data Analytics

Sr.No	Roll No.	Name of Student	IEM501	SGPA	TC	CGPA	Failed Courses
			4.00				
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IEM502 : OPERATIONS RESEARCH IEM504 : SUPPLY CHAIN MANAGEMENT IEM5210 : Contemporary Issues in Industrial Engineering and Managment IEM5304 : International Logistics and Warehouse Managment IEM5404 : INDUSTRY 4.0 & SMART MANUFACTURING

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2	23/IEM/01	RAVI RANJAN	O	B+	A+	A	O	8.82	17	
3	23/IEM/02	AATIF AMEER	A+	B+	O	A+	A+	8.65	17	
4	23/IEM/03	MAHESH SAROHA	O	A	A	A+	A+	8.88	17	
5	23/IEM/04	REDDI DUSHYANTH VENKATA SAI KRISHNA	A+	B	A	A	A+	8	17	
6	23/IEM/05	DIVYANSH	B+	P	B	B+	A+	6.65	17	
7	23/IEM/06	RAJENDER	A+	B	A	A	O	8.24	17	
8	23/IEM/07	PIYUSH KUMAR	A	B	A	A	O	8	17	
9	23/IEM/08	ISHAN KOTNALA	P	C	B+	B+	A	6.06	17	
10	23/IEM/09	LOKESH KUMAR	A+	A	A+	A+	A+	8.76	17	
11	23/IEM/10	DHRUV SHANKAR SAXENA	A+	A	O	O	O	9.29	17	
12	23/IEM/11	SHISHIR ACHARYA	A+	A	A	A+	O	8.88	17	
13	23/IEM/12	MORIE MEYER KOUNA FERRAND	A	C	A	A	A	7.29	17	
14	23/IEM/13	FREDRICK KABWE	A	B	A	A	A	7.53	17	

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1	23/IEM/501	PRAMOD	B+	C	5.8	5	

IEM601 : MAJOR PROJECT I IEM6201 : E- Commerce IEM6305 : GLOBAL BUSINESS MANAGEMENT IEM6405 : Advanced Operation Research

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2	23/IEM/01	RAVI RANJAN	A+	A+	A+	O	9.33	12	
3	23/IEM/02	AATIF AMEER	A+	A+	A+	B+	8.33	12	
4	23/IEM/03	MAHESH SAROHA	A	O	A+	O	9.25	12	
5	23/IEM/04	REDDI DUSHYANTH VENKATA SAI KRISHNA	A+	A+	A+	A+	9	12	
6	23/IEM/05	DIVYANSH	A+	A	B+	B	7.33	12	
7	23/IEM/06	RAJENDER	O	A+	A	A+	9	12	
8	23/IEM/07	PIYUSH KUMAR	A+	A+	B+	B+	7.83	12	
9	23/IEM/08	ISHAN KOTNALA	A+	A+	A+	B+	8.33	12	
10	23/IEM/09	LOKESH KUMAR	A+	A+	A+	B+	8.33	12	
11	23/IEM/10	DHRUV SHANKAR SAXENA	O	O	O	O	10	12	
12	23/IEM/11	SHISHIR ACHARYA	O	O	O	O	10	12	
13	23/IEM/12	MORIE MEYER KOUNA FERRAND	A+	A	A+	A	8.5	12	
14	23/IEM/13	FREDRICK KABWE	A+	A+	A+	A+	9	12	

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Amount :	₹2000
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Academic Year :	2024-2025
Branch Course :	M. Tech - Industrial Engineering and Management
Type/Name of fee :	Others if any
Remarks if any :	Thesis Submission Fee
Mobile No. of the student :	9899719963
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Name of the student :	RAJENDER
Academic Year :	2024-2025
Branch Course :	M. Tech - Industrial Engineering and Management
Type/Name of fee :	Others if any
Remarks if any :	Payment of Remaining Amount of Thesis Submission Fee
Mobile No. of the student :	9899719963
Fee Amount :	1000
Transaction charge :	0.00
Total Amount (In Figures) :	1,000.00
Total Amount (In words) :	Rupees One Thousand Only
Remarks :	Payment of Remaining 1000 rupee of Thesis submission Fee (Rs. 3000)

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May, 2025

ACKNOWLEDGEMENTS

Foremost, I immensely thank Almighty for the wisdom, blessings and inspiration throughout this research work. I embrace the opportunity to express my deep sense of gratitude to my supervisor **Dr. Mohd. Shuaib**, Assistant Professor, Department of Mechanical Engineering, Delhi Technological University, Delhi, for his constant guidance, valuable suggestions and encouragement during this research. His encouragement, support, intellectual stimulation, perceptive guidance, immensely valuable ideas, and suggestions from the initial to the final level enabled me to develop an understanding of the subject. His scholarly suggestions, constant help and affectionate behavior have been a source of inspiration for me. I am extremely grateful to him for his continuous guidance.

I am cordially thankful to the **Prof. Prateek Sharma**, **Hon'ble Vice-Chancellor**, Delhi Technological University, Delhi for providing this world class platform to conduct this research work. I extend special thanks to the **Prof. B.B. Arora**, **HOD** Department of Mechanical Engineering, Delhi Technological University, Delhi.

I am highly thankful to Mr. Roshan Kumar, Technical Assistant, Industrial Engineering Lab, Department of Mechanical Engineering, Delhi Technological University, Delhi for assisting in this research thesis.

I am thankful to Central library, Delhi Technological University for providing me the access to world class research literature and resources that helped me in this research work. I am thankful to all the authors and publishers whose research work has helped me in this research work.

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CANDIDATE'S DECLARATION

I, Rajender , hereby certify that the work which is being presented in the thesis entitled **"Towards A Bottom-Up Cost Model Framework For Freight Transportation In India : Road and Rail Perspectives"** in partial fulfillment of the requirements for the award of the Degree of Master of Technology, submitted in the Department of Mechanical Engineering, Delhi Technological University is an authentic record of my own work carried out during the period from 2023 to 2025 under supervision of **Dr. Mohd. Shuaib**, Assistant Professor, Department of Mechanical Engineering, Delhi Technological University, Delhi.

The matter presented in the thesis has not been submitted by me for the award of any other degree of this or any other Institute.

Candidate's Signature

This is to certify that the student has incorporated all the corrections suggested by the examiners in the thesis and the statement made by the candidate is correct to the best of our knowledge.

Signature of Supervisor **Signature of External Examiner**

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CERTIFICATE BY THE SUPERVISOR

Certified that **Rajender (**23/IEM/06) has carried out their search work presented in this thesis entitled **“Towards A Bottom-Up Cost Model Framework For Freight Transportation In India : Road and Rail Perspectives”** for the award of **Master of Technology** from Department of Mechanical Engineering, Delhi Technological University, Delhi, under my supervision. The thesis embodies results of original work, and studies are carried out by the student himself, and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

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Date - 30th May, 2025 Signature

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Towards A Bottom-Up Cost Model Framework For Freight Transportation In India : Road and Rail Perspectives

Rajender

ABSTRACT

India's road and rail haulage sector is crucial to the country's economy, but it faces challenges due to fragmented operations, diverse regional practices, inconsistent infrastructure quality, and an unstructured nature. Hence, it results in inefficiencies and more expensive logistics, and therefore, the need for an accurate cost model specific to the Indian context is proposed. This conceptual article conducts an extensive review of the global and domestic literature to identify critical fixed costs, variable costs, and miscellaneous cost elements in freight transport and logistics. This conceptual article included the bottom-up approach to the cost estimation model to enable a more thorough evaluation of transport expenses. The cost model is linked to a variety of networks with in the structured vehicular and rail transit freight transportation system. So as to achieve real-time coordination and monitoring within India's intermodal freight transportation system, a multi-faceted technological approach is employed. This intelligent freight transportation system is utilised for effective control of transport workflow. The theoretical application of the cost model framework is applied for the Delhi region, where it is shown that the systematic transportation framework and the intelligent freight transportation system has the potential to lower the transit time and cost of transportation in India. Moreover, the comparative assessment will analyse both the total and per-unit costs of moving freight through a road-and-rail star network, benchmarking the results against traditional long-haul road routes that traverse multiple states. Based on the outcome from cost analysis, the company management accepts effectiveness and the least expenses and minimal time duration of transit in a star network as compared to traditional long-haul road transportation. The study concluded that the proposed cost model has the potential for implementation in real-world scenarios, contingent on the development of the web application. The implementation of the cost model framework would facilitate informed decision-making among stakeholders, thereby improving the performance of the transportation sector of India while reducing overall expenses and promoting sustainability.

Keywords : Cost model, Road freight transport , Rail freight transport, infrastructure network, Intelligent freight transportation system, Bottom-up approach.

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LIST OF ABBREVIATIONS

Abbreviation	Full Form
PPP	Public Private Partnership
GNSS	Global Navigation Satellite System
DFC	Dedicated Freight Corridor
MMLP	Multi Modal Logistics Parks
GIS	Geographic Information Systems
ANNs	Artificial Neural Networks
DWC	District Warehouse Center
AI/ML	Artificial Intelligence / Machine Learning
IoT	Internet of Things
TMS	Transport Management Systems
ULIP	Unified Logistics Interface Platform
3PL	Third-party Logistics
1PL	First Party Logistics
RFT	Railway Freight Terminals
FOIS	Freight Operations Information System
FTL	Full Truckload
LTL	Less than Truckload
PTL	Partial Truckload
SPSS	Statistical Package for the Social Sciences
ERP	Enterprise Resource Planning
WMS	Warehouse Management Systems
IFTS	Intelligent freight transportation system

CHAPTER 1

INTRODUCTION

Freight transport is the circulatory system of the modern world. It has always been important to commerce and our society. While freight transportation is influenced by the requirements emanating from the manufacturing sectors and consumer behavior as discussed by Zeng & Rossetti, et al., (2003) and also shown that the cost related to freight shipping has evolved into a significant economic yardstick of supply chain efficiency. Road networks are massively misused while little is invested in already existing infrastructure, leading to such externalities including transportation congestion, greater energy consumption, and a negative environmental impact. Road capacity is constrained mainly outside of metropolitan areas, and some road segments in growing economies are in deplorable condition as discussed by Bhattacharya et al., (2013c).

Road transportation is considered one of the most cost-effective and preferred means of conveyance for cargo due to its comprehensive accessibility to densely populated regions. Consequently, it serves as a vital function in the economic advancement and social cohesion of the nation. Unlike rail or air transport, trucks can reach remote locations and provide direct delivery, making it essential for various industries. India is aggressively pursuing a multi-faceted strategy to reduce road freight transportation costs, with major infrastructure development projects at its core.

Bharatmala Pariyojana, launched in 2017, This initiative prioritizes enhancing connectivity between key manufacturing hubs, ports, and consumption centers, while simultaneously addressing congestion bottlenecks through strategic bypasses and ring roads around major urban centers. The Dedicated Freight Corridor (DFC) project, The DFCs are being constructed on the Mumbai-Delhi (Western) and Delhi-Kolkata (Eastern) segment of the Golden Quadrilateral. IR’s Golden Quadrilateral, Although it comprises only around 16% of the total route length, it handles over half of the railway’s total traffic, although focused on rail infrastructure, indirectly benefits road transport by transitioning certain freight volumes from road-based to rail-based transportation, thereby reducing congestion and improving overall efficiency as discussed by Indian Railways, (2023).

The development of Multimodal Logistics Parks (MMLPs) across India promotes efficient consolidation and distribution of goods, offering value-added services and seamless intermodal connectivity, further optimizing logistics operations and reducing costs as given in Ministry of Commerce and Industry, (2022). Multi Modal Logistics Parks (MMLP) are designed to lower aggregate freight expenses and transit durations, reduce warehousing expenses, mitigate vehicular emissions and traffic congestion, and increase monitoring and traceability of shipments through strategic infrastructural, procedural and technology investments at disparate locations across the country aimed to reduce logistics costs.

Currently, the road networks carry a higher proportion of freight in comparison to the rail network, with the ratio of freight on roads at 74% as compared to the 26% on rail. About 0.5% of the total road network are the main road networks that carry a dominating 40% of the freight being moved by road. This results in congested road networks near about 115-150% of the total capacity utilisation. Moving one tonne of cargo by road cost Rs. 2.50 per kilometre, by rail was Rs. 1.36, by water just Re. 1.06. After feasibility studies to make them navigable, IWAI has identified 26 new national waterways as stated in ports industry report, (2024). Freight transportation contributes to about 50 per cent of the logistics costs in India, and currently roads are the costliest and the slowest mode. In addition, the Indian government aims to cut down the logistics and supply chain costs in India from 13-14% to 10% of the GDP in line with industry norms. It should be noted that in financial year 21 the logistics industry was divided by section where road has the highest % age share as transport mode at 73%, this is followed by rail at 18%, inland water at 4% and air which also registers 6%. On the other hand, 10% is organized and 90% unorganized road transportation, bringing about the overload of trucks, recurring road accidents, the rapid ageing of vehicles and degradation of the roads has been adopted in literature by Gupta & Dhar, (2022). Freight logistics across road and rail networks is marked by a mix of organized and unorganized players, plays a critical role in supporting economic growth, bridging industrial supply chains, and catering to the demands of a rapidly growing population, demand and supply.

The bottom-up approach in transportation emphasizes the importance of local interactions and detailed data collection to inform decision-making and policy development. Bottom-up models can adapt to real-time data and changing conditions, making them suitable for dynamic environments like urban travel behaviour analysis as discussed by Das & Winter, (2016) . A bottom-up methodology in transportation cost modeling entails determining the overall cost of a transportation service by systematically identifying, estimating, and aggregating the expenses associated with each constituent component or operational activity involved in delivering the service.

Subsequent to this, an in-depth examination of the cost model will be presented, focusing on star infrastructure networks, which reduce total costs by 17-20% and the cost per metric tonne per kilometre ranges from 4.5 to 5.8 rupees. The findings aim to inform stakeholders-including policymakers, industry leaders, and researchers-about the relative advantages and trade-offs of each mode, thereby supporting evidence-based strategies for optimizing India's freight transportation along with sustainability.

1.1 Research Gap

i. Many existing models lack adequate consideration of ground realities such as informal transport sectors, overloading practices, empty running of trucks, small players in market, tax pyramiding, lack of Advance technologies integration, varying levels of infrastructure development across regions, and the impact of recent policy reforms like GST implementation of 5 and 12% .

ii. There is limited research on dynamic cost models that can accurately capture real-time fluctuations in variables like fuel prices, traffic congestion and geographical location.

iii. There isn't one single algorithm to determine road freight transportation costs in India. The existing cost models are only designed as per need of certain logistics company, and which is not applicable to India's unstructured transportation system.

1.2 Research Objective

i. To develop a comprehensive framework for understanding and estimating road freight transportation costs, which can help streamline cost estimation and enhance transparency.

ii. To develop the cost model in detail for three types of infrastructure networks, that are, line, ring and star networks and it will account for the heterogeneity of the sector and incorporate strategies & cost model to deal with data limitations and uncertainties associated with the unorganized segment.

iii. To develop the web app Central theme of technological advancements known as Intelligent freight transportation system, formed by ULIP, AI and IoT and cost model.

CHAPTER 2

LITERATURE REVIEW

Road haulage is the vital of India's rapidly evolving economy, facilitating the transportation of items across significant distances and varied terrains. Understanding the cost structure of this crucial sector is essential for efficient logistics planning, pricing strategies, and infrastructure development. This literature review examines existing research on cost models for road freight transportation in India and other countries. Furthermore, this study aims to highlight limitations and unexplored dimensions within existing scholarly work and suggest potential avenues for future research in this domain.

In the literature by Izadi et al., (2020) presents various cost models. These models separate these costs into three categories: These can be classified as operating cost, value of time (VOT) and externality cost. The most fundamental techniques of approach to assessment of methods and measuring model of data collection structure in general are. The application of fuzzy approximations in modelling might help increase the accuracy of results. Prior studies indicate that the fuzzy techniques are not adequately incorporated in this area of study.

The research has been discussed by Zeng & Rossetti, (2003) aims to address the complexities involved in evaluating total logistics costs within international supply networks, especially concerning a prominent corporation in the United States aerospace sector and its corresponding supplier located in China. The authors propose a five-step evaluation framework that can be implemented using spreadsheet tools, allowing for flexibility in assessing various transportation alternatives and conducting sensitivity analyses. The results suggest that the logistics expenses make up a considerable part of the overall worldwide sourcing expenditures, which can influence the effectiveness of procurement strategies.

The study by Lingaitiene et al., (2008) focuses on building a mathematical to strategic model for determining cost-efficient and time-effective paths and transport facilities for multimodal freight transportation.

The study by Ďurišová et al., (2011) examines the use of cost models in transportation companies to enhance operational efficiency and cost reduction strategies. As a further point, the research relies on information obtained from a designated transportation company, which could restrict the applicability of the results to different settings or scenarios. Applied models have the drawback of being static and having varying degrees of influence on various parameters.

The investigated methodologies for calculating costs in the domain of road freight logistic, focusing on developing a more precise method for determining the upfront cost incurred in executing a particular transport activity. A software application was developed based on the proposed method, enabling transport companies to calculate first costs quickly and precisely. Findings indicate that the developed approach ensures cost accuracy within a 3.5% margin, significantly outperforming traditional estimation methods that deviate up to 12 as discussed by Kovács et al., (2017).

The study investigated by Kulovic & Se, et al., (2004) discussed the factors influencing road freight transport costs, focusing on the impact of truck fleet operational parameters. The research found that lost time, including waiting time and travel time, significantly influences transport costs.

The rising of handling costs at terminals, greater total transport distance, elevated pre- and post-haulage costs, greater distance-related marginal generalized costs of rail, lesser distance-related marginal generalized costs of truck, and decreased resting costs in case of truck drivers as discussed by Hanssen et al., (2012).

The development of comprehensive model to evaluate and compare the total costs incurred by intermodal infrastructures. Key findings reveal that intermodal networks benefit from economies of distance and scale, with cost reductions accelerating over longer distances and higher service frequencies as discussed by Janic et al., (2007).

The research study by Cheng et al., (2009) delve into the intricate world of intermodal freight transport costs, aiming to establish a clear and universally accepted method for their calculation. The authors highlight the significance of considering factors such as design, coordination, and random costs, often overlooked in traditional cost calculations.

A study by Conrad et al., (2018) examined the expenses and obstacles associated with transporting logs by truck. The research involved interviewing 18 log truck owners who operated in Georgia, USA. Findings revealed that the most significant challenges were Shortage of adequately trained driving personnel and the escalating cost of truck insurance. Also provide driver education and deploying technologies such as GPS tracking and in-vehicle cameras.

In the European metropolitan setting by Kordnejad et al., (2014) examined the intermodal distribution and the multimodal transport cost model and research aims to develop a conceptual framework for implementing a regional intermodal transportation system using rail for a distributor of essential consumer goods operating within an urban environment. Transport system and assess its cost and emissions. According to the findings, the overall expenditure associated with transporting goods by road encompasses both the costs incurred before and after transit to terminals. Similarly, the complete expenses linked to terminal operations are contingent upon the per-unit transfer costs specific to each terminal type.

The study by Levinson et al., (2005) conducted an analysis of the operating expenses associated with trucks. A survey targeting companies engaged in commercial truck transport was executed. And result in comparable ability for measuring total costs based on data. Furthermore, the models indicated the 1% rise in output total truckloads results in a 1.04% rise in total costs.

The study by Qiao et al., (2019) investigated a decision-making conundrum pertaining to dynamic pricing for less-than-truckload shipments within the framework of the Physical Internet (PI). The research outcomes revealed that the proposed model possesses the potential to enhance the bidding price of carriers, thus augmenting anticipated profits, and three pivotal factors were investigated: the number of calls, the capability of the carrier, and the cost of the service.

The research by Zofío, Condeço-Melhorado, et al., (2014) investigated the overarching costs associated with freight transportation by employing a geographical analysis of economic and infrastructural fundamentals. Generalized transport Costs GT C within a value index of transit can be a deflator that separates cost and volume index for economic market transport costs within the necessary transport network, distance and time. The changes in road freight movement in Spain has been analyzed in detail from 1980 to 2007 at disaggregate geographical level. The mean GTCs, adjusted for trade movement, has experienced a decline of 16.3%, with infrastructural developments facilitating this reduction.

The study proposed by Z. Zhang & Eng, (1993) to optimization framework for scheduling freight truck drivers predicated on an operational cost assessment model adapted to the operational structure of Less-than-Truckload logistics services. They presented a special time driven ABC model was oriented majorly towards improving efficiency in truck freight businesses. In addition, ANN model was developed to establish relations between fuel usage and driving behaviour. The limitations in prior models for estimating transport costs by proposing a comprehensive framework that incorporates factors such as transport supply and demand, infrastructure quality, route-specific characteristics, and firm-level strategies.

Utilizing data from 583 interviews and 6,390 observations across 305 routes within Europe, identifies both linear and quadratic relationships between distance and transport costs, providing nuanced insights into modal preferences and cost behaviours over varying distances. The model's predictive power (adjusted $R^2 = 0.814$)

underscores its robustness, that has been adopted in literature by Camisón-Haba & Clemente-Almendros, (2020).

This systematic literature review by (Barakchi et al., 2017) investigates the various cost estimation methods used in transport infrastructure projects. The review identified around 12 distinct cost estimation methods, with the parametric, ANNs are mostly used in many literatures. The authors discuss how these methods differ in terms of accuracy, usability/application, and ease of understanding key attributes that influence their suitability for specific transport infrastructure projects.

The study by Fumasoli et al., (2016) has discussed that four alternative scenarios are developed for integration of urban rail into a freight system and then evaluated based on a Business as Usual scenario. Emissions, handling time and fuel consumption metrics are analyzed, with results showing significant benefits in decreasing emissions by 97.8% down to BAU by 2026.

The study by Callefi et al., (2022) responding to an important knowledge gap in the literature, to identify and evaluate technology enabled capabilities that constitute road freight transportation systems, a multi method study is based on this. The authors employ a comprehensive multi-methodological framework that integrates a systematic review of existing literature alongside the analysis of secondary data sources. and expert validation to note their end. Based on the SLR, we identify 32 distinct technology enabled capabilities, distributed into six groups, and discussing the role that each of these technologies, namely those of I4.0 like blockchain and IoT, plays in optimizing freight transportation operations. Results of the findings show that 28 out of the 43 capabilities on the scale had commercial applicability and stakeholder information value to the industry including shippers and carriers with respect to how ready these capabilities might be to be implemented.

The research by Kumar et al., (2019) was primarily designed to deal with complexity of sustainable freight systems through development of analytical models to support making choices in logistics. As part of the objectives, a bi-objective optimization model is to be developed to minimize transportation costs and carbon emissions and explore intermodal transportation system within the Turkish transportation industry.

The study methodologically employs the ε-constraint method and ODS to obtain Pareto optimal solutions that trade off cost and environmental impact. Experiments show how the proposed models produce feasible solutions that are 3 to 7% faster than the existing algorithms, this helps logistics companies to reduce their operating expenses as discussed by Carboni & Dalla Chiara, (2018).

The rail freight is recognized for its lower carbon footprint and reduced external costs has been extensively investigated by Dhulipala & Patil, (2024). The main findings are the functional relationships among the various ways of transport. The research by

Ravibabu et al, (2013) examines the variables that affect the choice of inland transport modalities for containerized export freight in India.

Sachan et al., (2024) has presents a comprehensive study aimed at addressing the inefficiencies in logistics transportation planning, particularly within the context of the One District-One Product initiative in Uttar Pradesh, India. This investigation seeks primarily to establish a novel cost function that incorporates various cost components, including unit transportation costs, labour costs, operational costs of spokes, and establishment costs of hubs, thereby providing a more accurate representation of logistics expenses. To achieve this, the authors employed a meta-heuristic approach, utilizing eight well-established algorithms to solve the logistics optimization problem.

The research by Sharma et al., (2024) aims to analyse the Indian railway freight business, employing a multifaceted methodology that includes literature reviews and data from the Indian Railways Year Book . Key findings indicate a decline in freight performance due to competition and inefficiencies, with recommendations for future studies on sustainability and operational improvements . Limitations include reliance on secondary data, suggesting a need for primary data collection in future investigations.

The study by Bhattacharya et al., (2014) has delved into the complexities of intermodal freight transport systems, with a particular focus on enhancing the performance of supply chain logistics. The methodology employed involves a two-step process. The MIP optimization model successfully identifies cost-effective and time-efficient intermodal transport strategies, assess the trade-off between operational expenses and transit delays.

Singh & Gupta, (2020) has explores if and how the urban rail infrastructure of the Delhi Metro and Ring Rail systems could be used to distribute freight, focusing with the postal and courier services. By examining whether these existing, underutilized passenger rail systems during off peak hours can be repurposed to carry urban freight as a way to relieve congestion and reduce pollution while improving efficiency by passively taking advantage of the declining passenger load in benefitting from the existing infrastructure and train fleets and operating cycles of the current passenger trains without capital expense.

Freight transport research increasingly relies on statistical tools to analyse, forecast, and optimize operations. SPSS (Statistical Package for the Social Sciences) is a widely used software in this field, supporting data analysis, prediction, and decision-making processes for freight companies as discussed by Younes & Naji, (2022).

The study discussed by Ambast et al., (2024) examines GST's impact on profitability in logistics by comparing pre- and post-GST data from 2013 to 2022 for six companies using Shapiro Wilk tests, correlation analysis, and paired t-tests in R Studio. Results reveal that GST significantly improved profitability in logistics while impacts on education and hospitality were mixed or statistically insignificant. Limitations include small sample size and short duration, suggesting future broader, longitudinal research.

2.1 Bibliometric analysis of freight transport.

Bibliometric analysis aiming to uncover patterns, trends, and the structure of research within a specific domain. It is prominent approach for reviewing and analysing scientific publications, as stated by Merigó & Yang, (2017) . In this investigation, we used the bibliometrix R-package produced by Aria & Cuccurullo, (2017). This study utilizes SCOPUS and Web of Science (WOS) database was employed as the primary source for literature retrieval to maintain a high standard of scholarly quality in the reviewed studies. In Fig. 2.1, word cloud of most frequent keywords identified by bibliometric analysis is shown. The top five words with frequent occurrence are sustainability, logistics, transportation, supply chain and India.

Fig. 2.1: Word map of most frequent keywords (source: R- Shiny)

Fig. 2.2 shows the frequency of words of most frequent word in100 selected research articles, and it can be concluded that industry 4.0 in freight transportation is having most appearance in research articles since 2015.

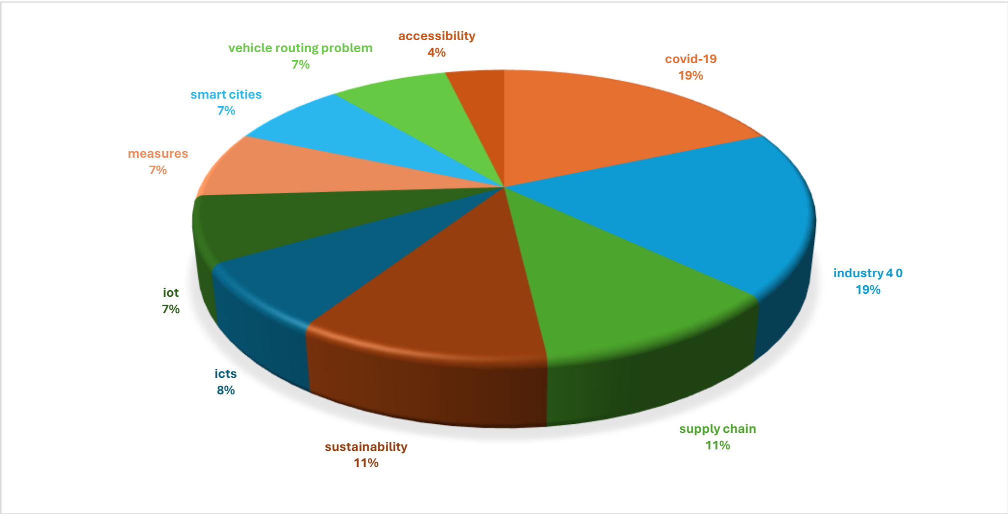

Fig. 2.2: Pie chart of Most Frequent Words (source: R- Shiny)

The Fig. 2.3 shows the co-occurrence network, generated using VOS viewer, of main keywords namely, road transport, rail transport, logistics, performance measures, etc.

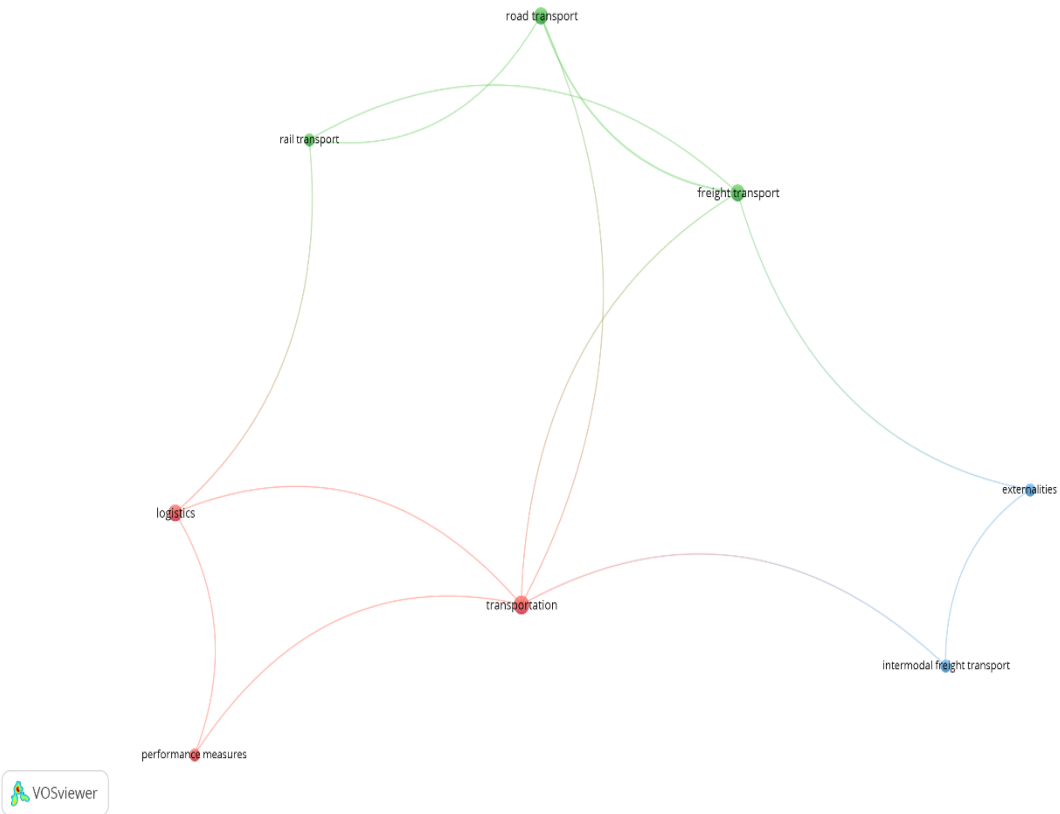

Fig.2.3: Keyword co-occurrence network structure (source: VOSviewer)

The fig. 2.4 show the interconnection of 40 research articles in similar work of corresponding authors in the span of 10 years. The maximum interconnection of similar work is obtained by Mostert et al., (2017a) and Janic et al., (2007) . Therefore organize, analyse, and connect ideas from existing literatures to cost model development

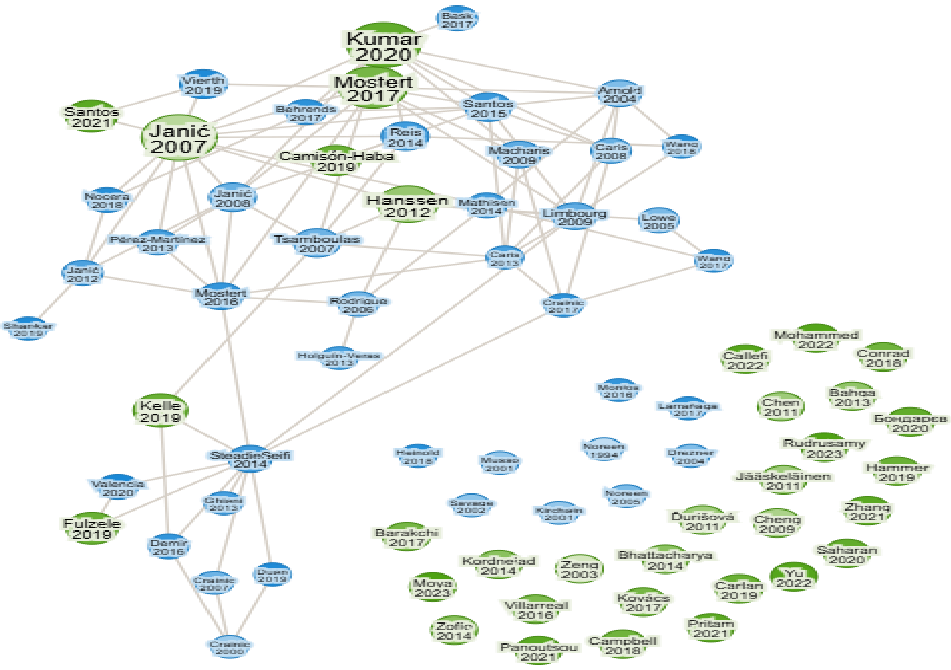

Fig. 2.4: Similar work interconnection graph (source: R- Shiny)

Fig. 2.5 shows the sources' production over time period of 10 years of words over time, and it can be stated that Transportation research Procedia published articles.

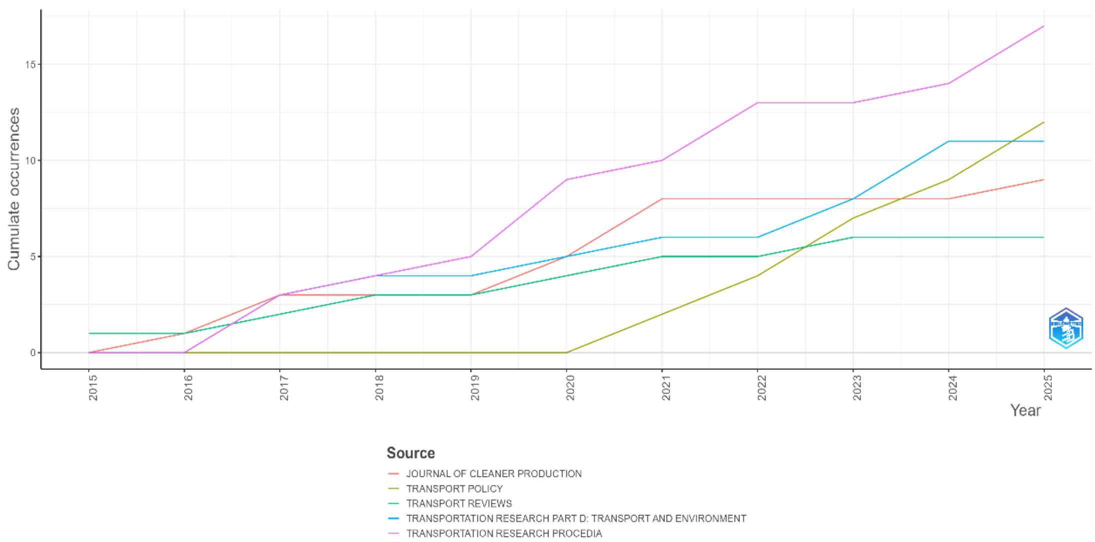

Fig 2.5: Sources' production over time (source: R- Shiny)

In the three-field plots shown in Fig. 2.6, interconnection between 15 sources, 12 keywords and 15 abstracts is shown. The main relationships are shown below in figure with words being sustainability, transportation, decarbonization, freight, etc.

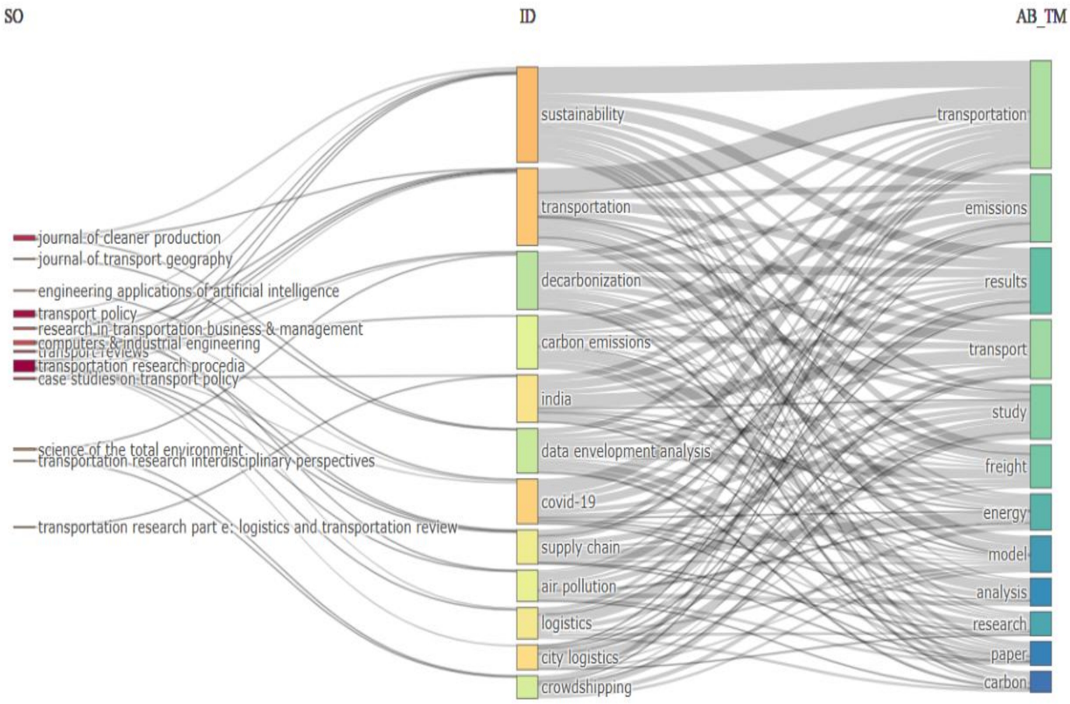

Fig. 2.6: Three-field plot of keywords, sources and abstracts. (source: R- Shiny)

2.2 Cost Factor Identification and Selection

This literature review has examined existing research on road freight transportation cost models revealing a diverse range of approaches and methodologies. Studies have explored various factors influencing costs. Table 2.1 summarises the essential elements of these research, including their major cost classification and a freight cost calculation approach adopted in this research. The considered publications are also grouped into Factors impacting road and rail Freight Transportation Cost in Table 2.2. This methodology utilizes a simplified analytical framework that identifies the key cost components of the transport chain, both internal and external. It turns out that the economic benefits of rail-road combined transport to rail - road alone depend very strongly on the level of efficiency of pre and post transport phases, and from that point of view the economic benefits of rail-road are not so sufficient to take advantage of the combined transport option. In this study to further refine the cost estimation, the model should incorporate the following factors in Road-Rail freight transportation, and these final factors are shortlisted based on drawing upon existing scholarly research and the survey of logistics companies and freight forwarder to identify the key cost factors for the application of proposed method. A thorough description of these cost factors is given in Table 2.3. But of course, the foremost financial planning is must to have the business running and financial Plan is mandatory where a comprehensive outline of your initial investment, how you'd be funding much of the endeavour with various sources, projections on the revenue that is going to help you set your expected financial outlook, and all the calculations that are going to help you determine your profit margins from this venture. In general, the profit margins observed in the transport industry can be highly variable and appropriately on the order of 10 percent to as high as 30 percent, which is strongly impacted by the efficiency of such management practises and projected demand, competition, seasonality, and varied terrain across India affecting business activities.

Table 2.1. An overview of the research articles on freight cost estimation

References	Cost Classification		Methodology								
	Operational	Externalities	ABC	Mathematical	Statistical	Survey	Data Mining	GIS	Meta-Analysis	Fuzzy	others
Zeng ,Rossetti, (2003)	⊙	⊙			⊙						
Ravibabu et al., (2013)	⊙										⊙
Bhattacharya et al., (2013)	⊙			⊙							
Sachan et al., (2024)	⊙			⊙							
Ďurišová et al., (2011)	⊙										⊙
Kovács et al., (2017)	⊙			⊙							
Kulović et al., (2004)	⊙				⊙						
Hanssen et al. ,(2012)	⊙			⊙							
Janic et al., (2006)	⊙	⊙			⊙						
Yao-Rong et al., (2009)	⊙			⊙							
Bierwirth et al., (2012)	⊙			⊙							
Carlan et al., (2019)	⊙	⊙		⊙		⊙					
Conrad et al.,(2018)	⊙										⊙
Kelle et al., (2018)	⊙	⊙		⊙							
Kordnejad et al., (2014)	⊙	⊙			⊙						
Levinson et al., (2005)	⊙		⊙			⊙					
Lindsey et al. (2013)	⊙						⊙	⊙			
Mostert et al., (2017)	⊙	⊙							⊙		
Qiao et al., (2016)	⊙			⊙							
Radhakrishnan & Anukokila, (2014)	⊙									⊙	
Zofio et al.(2014)	⊙						⊙	⊙			
Zhang et al., (2018)	⊙		⊙	⊙							

Table 2.2. Key elements contributing to the financial outlay in freight logistic

Factors that influence cost				
Operational costs		Value of Time	External Costs	
Fixed costs	variable costs			Reference
i. Order processing ii. Administration Costs iii. Customs clearance Fees iv. Brokerage fees v. Allocation fees vi. Packaging/supplies Costs	i. Consolidation fees ii. Transfer fees iii. Pickup and delivery charges iv. Pipeline holding costs v. Terminal handling charges vi. Material handling costs vii. In/out handling charges viii. Disposal charges	i. Transit times ii. Manufacturing time	i. Damage/loss/delay cost ii. Insurance	Zeng & Rossetti et al., (2003)
i. Terminal handling costs	i. Haulage costs ii. Repositioning charges	i. Transit time ii. Detention at terminals	i. Loss and damage cost	Ravibabu et al., (2013)
i. Crew operating costs ii. Maintenance iii. Fuel costs.	i. Vehicle transfer/transshipment costs ii. Loading and unloading costs iii. Drayage costs	i. Transit times		Bhattacharya et al., (2014)
i. Vehicle excise duty ii. Vehicle insurance iii. Drivers' guaranteed wages iv. Overheads v. Capital investment vi. Insurance vii. Registration fees	i. Fuel cost ii. Fuel taxes iii. Oil cost iv. Tires v. Maintenance and repair vi. Crew wages vii. Paid parking viii. Toll taxes	i. Travel time ii. Reliability iii. Frequency iv. Flexibility	i. Environmental cost ii. Accidents iii. Congestion	Izadi et al., (2020)
i. Technological Costs ii. Driver Payments	i. Fuel Costs ii. Maintenance and Repairs: iii. Road Taxes iv. Loading and Storage Costs	i. Total Time Expenses ii. Relative Expenses in Terms of Time(delay time)	i. Insurance Expenses ii. Non-provisioned Downtime	Lingaitiene et al., (2008)
i. Vehicle Depreciation ii. Liability Insurance iii. Accident insurance iv. Realtrans Charges v. Wages of drivers vi. Vehicle Insurance	i. Fuel consumption ii. Tyre abrasion iii. Oils and lubricants iv. Service and maintenance		i. Technical Requirements for Vehicles	Ďurišová et al., (2011)

Table 2.2 Continued

Factors that influence cost				
Operational costs		Value of Time	External Costs	Reference
Fixed costs	variable costs			
i. Truck payments ii. Licenses, tags	i. Driver wages, benefits, and overhead ii. Fuel cost iii. Tires cost iv. Maintenance and repair			Conrad et al., (2018)
i. Infrastructure investments ii. Terminal and yard facilities	i. Fuel consumption ii. Labor costs iii. Vehicle operating costs	i. Travel time ii. Reliability	i. Traffic congestion ii. Accidents	Kelle et al., (2019)
i. Infrastructure Costs ii. Terminal Handling Costs	i. Operational Costs ii. Loading and Empty Run cost	i. Transportation Time ii. Service Times at Nodes	i. Environmental Impact ii. Congestion Costs iii. Reliability and Punctuality	Kordnejad et al., (2014)
i. License Fees ii. Insurance iii. Interest Charges of vehicles	i. Fuel Consumption ii. Engine Oil Consumption iii. Tire Costs iv. Maintenance Costs	i. Driving Conditions ii. Length of Hauls	i. Policy Restrictions ii. Environmental Impact	Levinson et al., (2005)
i. vehicle Type: The type of truck used (e.g., van, flatbed, refrigerated)	i. Distance ii. Number of Stops iii. Cargo Type iv. Lead Time	i. Seasonality ii. Market Conditions		Lindsey et al., (2013)
i. Infrastructure Investments ii. Terminal Capacity	i. fuel costs ii. maintenance iii. labour		i. Human Health External Costs: ii. Air Pollution Costs	Mostert et al., (2017)

Table 2.2 Continued

Factors that influence cost				
Operational costs		Value of Time	External Costs	Reference
Fixed costs	variable costs			
i. Amortization cost of vehicles ii. Insurance costs	i. Cost of transport way with/without useful load ii. Fee of motorway usage iii. Cost of waiting time during the transport way iv. Driver's labour costs v. Maintenance cost of vehicles			Kovács et al., (2017)
i. Drivers ii. Depreciation and Interest iii. Overheads	i. Fuel ii. Lubrication Oil iii. Tires iv. Spares			Kulovic & Se, (2004)
i. Terminal Handling Costs	i. Pre- and Post-Haulage Costs ii. Long-Haul Transport Costs	i. Transport Time ii. Time Cost of Freight iii. Resting Costs for Truck Drivers		Hanssen et al., (2012)
	i. Truck operation cost ii. Main transport mode cost (intermodal network) iii. Handling cost	i. Time cost of goods in transit	i. Time cost of goods in transit ii. Congestion iii. Traffic accidents	Janic et al., (2007)
i. Design cost ii. Exclusive cost	i. Transshipment cost ii. Loading and unloading cost	i. Time value cost	i. Random cost from unpredictable external factors	Cheng et al., (2009)
	i. Full-train-load cost ii. Less-than-train-load cost iii. Terminal handling charges	i. Transit time		Bierwirth et al., (2012)
	i. Time and Distance Costs ii. Tolls and Fees iii. Truck and Chassis Usage Costs		i. Emissions cost	Carlan et al., (2019)

Table 2.2 Continued

Factors that influence cost				
Operational costs		Value of Time	External Costs	Reference
Fixed costs	variable costs			
i. Labour Costs ii. Financial Costs iii. Insurance Costs iv. Taxes v. Administrative overheads Operating expenses vi. Commercial costs	i. Fuel Costs ii. Maintenance Costs	i. Value of Time Indices(taking into account various characteristics that affect time and distance)	i. Environmental Costs ii. Congestion Costs	Zofío, Condeço-Melhorado, et al., (2014)
i. Vehicle costs ii. Insurance fees iii. Licenses and permits	i. Fuel costs ii. Repair and maintenance fees iii. Tolls Taxes	i. Time spent on administrative activities ii. Time spent on rest breaks due to Hours-of-Service	i. Environmental costs ii. Accidents iii. Traffic congestion iv. Noise pollution	Z. Zhang & Eng, (1993)
	i. Distance ii. Volume of Freight iii. The degree of competition among logistics operators	i. Transit Time	i. Energy Consumption ii. Logistics Efficiency	Camisón-Haba & Clemente-Almendros, (2020)
i. Infrastructure Costs ii. Vehicle Ownership Costs	i. parking pricing ii. Energy Costs for Electric Vehicles (EVs)	i. congestion pricing ii. Schedule Delay	i. Environmental Costs ii. Accident Costs	Saharan et al., (2020)
i. depreciation of Vehicles ii. Insurance Costs iii. Licensing and Registration Fees	i. Fuel Consumption ii. Toll Fees iii. Repairs & Maintenance Costs	i. Travel Time ii. Waiting Time	i. Environmental Impact Costs ii. Congestion Costs iii. Accident Costs	Fulzele et al., (2019)
i. Establishment Costs of Hubs ii. Rental Costs of Distribution/Collection Centers (DCCs)	i. Transportation Costs ii. Loading/Unloading Costs	i. Transportation Time	i. Environmental Costs ii. Market Competition Costs	Sachan et al., (2024)

Table 2.3: Description of cost factors selected for the cost model

Cost Factor	Description	References
Distance travelled	This is a primary cost generally increasing with distance travelled.	(Camisón-Haba & Clemente-Almendros, 2020), (Ahmad et al., 2024)
Administrative and online services	Refers to expenses incurred for managing operations, documentation, legal compliance, SEO, Social Media Marketing and Website Creation	(Zeng & Rossetti, 2003) , (Zofío, Condeço-Melhorado, et al., 2014)
Commercial Vehicle cost	Different vehicle types have varying operating cost and depreciation cost over the vehicle's useful life [own vehicle] Selective Rental vehicle cost	(Saharan et al., 2020) , (Bhattacharya et al., 2014) , (Izadi et al., 2020) , (Lindsey et al., 2013)
Useful Load	The weight and volume of the cargo influence fuel consumption and overall costs	(Kovács, 2017), (Cheng et al., 2009), (Santén, 2017)
Mileage	Number of miles a vehicle can travel per unit of fuel consumed, (km/L). changes significantly with topographical conditions and useful load.	(Taefi et al., 2017), (Gerondeau, 1996)
Fuel Prices	Fluctuations in fuel prices of different types of fuel, which directly impact transportation costs, influence the variable cost per km. considering fuel efficiency.	(Z. Zhang & Eng, 1993), (Mostert et al., 2017b), (Conrad, 2018)
Fuel consumption	Fuel consumption is the amount of fuel used by a vehicle to travel a distance.	(Fulzele et al., 2019),(Levinson et al., 2005), Ďurišová, 2011)
Toll Charges , Taxes and national permits	Toll charges in India are fees collected for using specific roads or highways, taxes include vehicle tax imposed by the government, and national permits allow commercial vehicles to operate across multiple states.	(Fulzele et al., 2019), (Zofío, Condeço-Melhorado, et al., 2014)
Driver and support staff cost	Maintenance crew cost (if in-house) during travelling plus Driver Base salary plus daily allowances for food and lodging, and benefits of insurance . [own driver] external driver (outsourcing) cost.	(Bhattacharya et al., 2014), (Conrad, 2018), Kulovic & Se, 2004.)
Maintenance and spare parts cost	Maintenance and spare parts costs in road freight transportation encompass expenses for upkeep, repairs, and replacement parts to keep vehicles and equipment operational.	(Fulzele et al., 2019), (Z. Zhang & Eng, 1993), (Conrad, 2018)
Insurance and EMI cost	In India, insurance refers to a premium paid for financial protection of assets like vehicles, while EMI a fixed monthly payment for repaying loans.	(Fulzele et al., 2019), (Zofío, Condeço-Melhorado, et al., 2014)
Loading-unloading Labour Costs /handling charges	Costs associated with loading and unloading cargo at the origin and destination, it is varied according to good and material types to be loaded, Packed, and palletized.	(Hanssen et al., 2012), Zofío, Condeço-Melhorado, et al., 2014), (Sachan, 2024)
Licensing and Registration Fees(RTO charges), fitness certificate charges	RTO charges in India include registration, road tax, and transfer fees for vehicles, while fitness certificate charges are fees for certifying a commercial vehicle's roadworthiness.	(Fulzele et al., 2019), (Saharan et al., 2020), (Levinson et al., 2005)

Table 2.3 (continued)

Factor	Description	References
Overhead costs / Infrastructure Costs	Core transportation activities in road and rail freight operations have expenses that support their operations without directly participating in freight movement. The infrastructure costs in road and rail freight transport refer to the capital and operational expenditures for building, maintaining.	Kulovic & Se, (2004), Izadi et al., (2020), Saharan et al., (2020), Mostert et al., (2017)
Transporter margin %	Percentage of Revenue remaining after deducting all operating costs.	Danylenko & Borovik, (2022) , Nuño-Ledesma & Villoria, (2019)
Wagon type	It Refers to the specific category of rail freight wagons designed to transport different types of goods	Moya et al., (2023), Wiesław et al., (2016)
Cargo Type / commodity category	The classification of goods based on their nature, size, weight, or handling requirements for transportation and logistics. For exam Bulk Cargo, Containerized Cargo, Specialized Cargo, Liquid and Gas Cargo.	Zhao et al., (2024), Gera et al., (2024)
Parking cost	Parking cost refers to the fee charged for temporarily parking a vehicle in designated spaces, such as public lots, garages, or private areas.	Saharan et al., (2020) , Alho et al., (2022) , Campbell et al.,(2018)
Container Costs	Cost incurred for selecting special container as per types of goods loaded	Ding & Wang et al., (2022)
Environmental Costs	Environmental costs refer to the air pollution, greenhouse gas emissions, and noise pollution caused by transportation activities	Sachan et al., (2024) , Saharan et al., (2020) , Zofío, Condeço-Melhorado, et al., (2014), Izadi et al., (2020)
Cargo Insurance	Coverage for goods-in-transit and any claims arising from accidents or damage.	Cueva Clemente et al., (2022), Kotenko et al., (2022) , Kang et al., (2020)
GST	GST on rail and road freight transportation in India is generally levied at 5%, with some exceptions and variations depending on the specific goods and services involved	Ambast et al., (2024) , Fulzele et al., (2019)
Transit times	Cost varies according to date and time of delivery	Sachan et al., (2024) , Camisón-Haba & Clemente-Almendros et al., (2020)
Market Dynamics	Consider supply and demand factors and competition in the region, which can influence pricing and availability of trucks.	Li et al., (2018) , Baindur & Viegas, (2011)
Freight Tariff	It is the rate charged by a railway operator for transporting goods, determined by factors such as commodity type, distance, wagon type, and applicable surcharges.	Vydashenko & Askarova, (2024), Smith et al., (2007), (Sharma et al., 2024)
Warehousing charges for storing	It refer to the fees levied for holding goods in a storage facility, based on factors like duration, space occupied, and special handling requirements.	Tikito et al., (2010), (Pan & Yang et al.,(2021)

CHAPTER 3

FORMULATION OF THE PROBLEM AND SOLUTION APPROACH

3.1 Method selection

For determining the effective cost in terms of Rupees per metric ton per kilometer within the expansive and complex landscape of the Indian road- rail freight transportation sector are of paramount importance. In order to achieve this, a Bottom-up approach to cost estimation model tailored for Road and Rail freight operations in India would employ a meticulously structured approach that seamlessly incorporates a multitude of key variables that significantly influence transportation costs. Subsequently, the mathematical model would delineate and establish intricate relationships between these identified parameters, thereby elucidating their interdependencies and collective impact on overall cost calculations. The model for road and rail freight in India would utilize a structured approach that includes different infrastructure network and examines model based on fixed costs , variable costs, Miscellaneous Costs. Next, the model would establish mathematical relationships between these parameters. It would then integrate these individual cost components into a comprehensive formula. By methodically inputting specific shipment details into this sophisticated model, one could derive a highly reliable estimate of the overall costs associated with road - rail freight transport.

3.2 The Conceptual Framework of Cost Model

In the Indian context, a limited number of logistics enterprises possess proprietary commercial vehicles designated for transporting goods from manufacturers to retail outlets or distribution centres. Conversely, most logistics firms engage with freight forwarding vendors or third-party logistics (3PL) service providers, who procure freight quotations predicated upon the shipment specifics provided. The Fig. 3.1 shows the conceptual framework depicting the Structured approach to Road and Rail Freight Transportation. It outlines key steps for converting from an unstructured to a more structured road freight transportation system in India. It begins by characterising the current unstructured scenario and proceeds towards the creation of a structured system through data collection, policy formulation, infrastructure development, technological integration of Fuel Efficiency, AI and IoT, and ULIP for both inhouse and outsourced transportation services and finally structured and regulated system becomes the catalyst for cost reduction and system modernization.

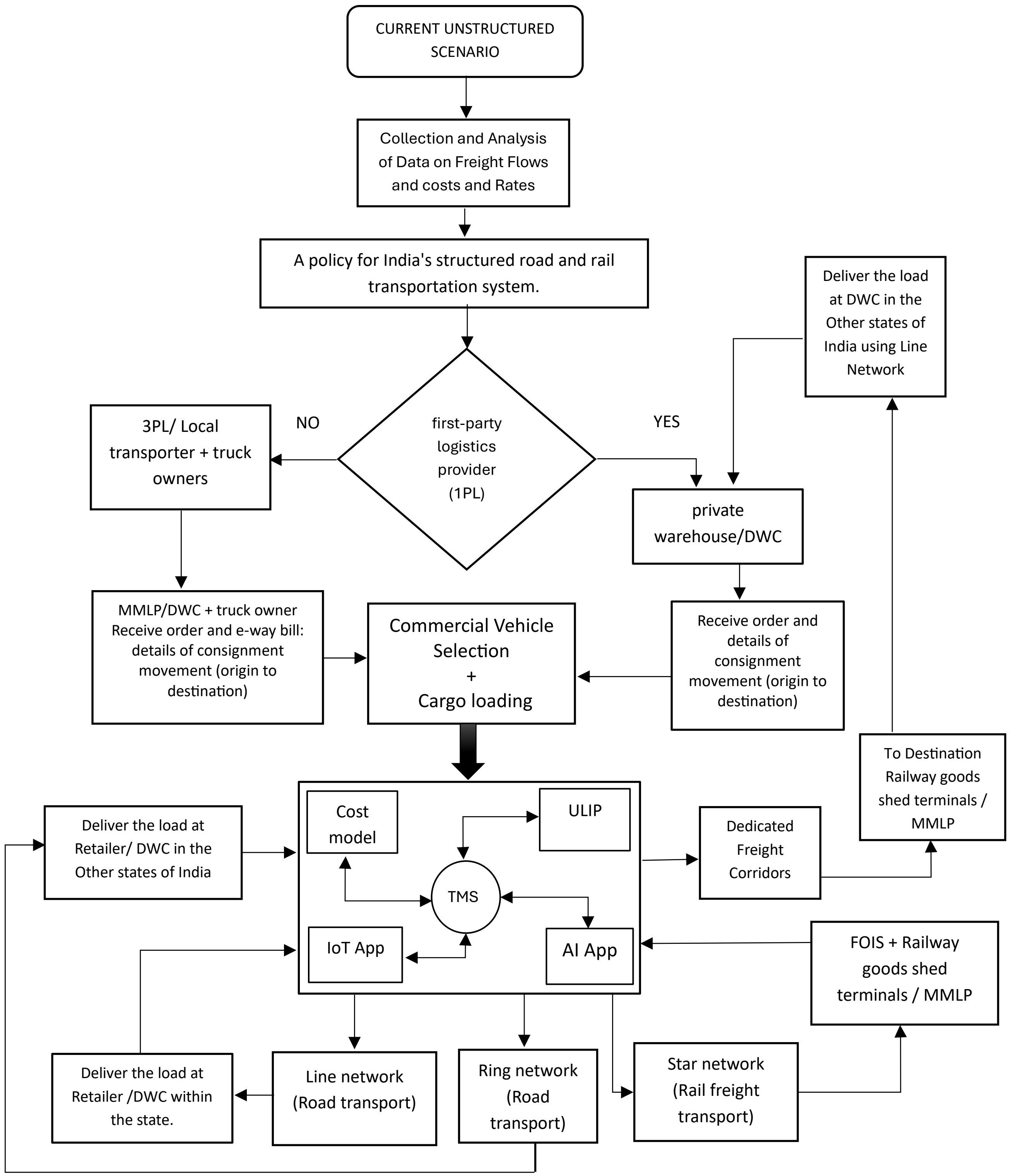

Fig. 3.1: Conceptual framework of the structured Road-Rail Freight Transportation

3.2.1 Current scenario

The road freight sector in India exhibits a significant level of fragmentation. Approximately 75% of the market is accounted for by small owner-operators with up to five trucks. In contrast, large fleet operators with more than 20 trucks account for a mere 15% of the market. Small players encounter challenges in optimising driving patterns and lack the resources to invest in larger vehicles, digital tools, software, and expertise. This market structure gives rise to reduced asset utilisation. This has been shown to result in inefficiencies and higher costs. Furthermore, the 3PL company failed to verify and authenticate the owner and driver of the local trucks, resulting in theft and damage to transit inventory.

3.2.2 Collect and analyse data on freight flows and movements

To adequately analyse India's freight transportation network, extensive surveys and stakeholder interviews is conducted. This procedure depicted in figure 3.2, entail collecting data Prior to the formulation of an output for the cost model, from a variety of sources, including toll plazas, RTO office, freight brokers, logistics companies, and NHAI, NITI Aayog, NICDC Logistics Data Services (NLDS), MoRTH of Government of India, central warehousing corporation of India, FOIS Indian railway, local transporters and logistics companies.

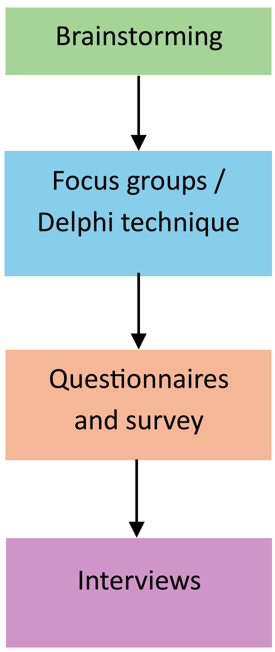

Fig. 3.2 : Procedure of data collection

3.2.3 Draft a policy for India's structured road and rail transportation system.

To ensure a strong and inclusive approach to organizing and regulating India's road freight transport system, a national-level strategy should be devised in collaboration with stakeholders. This policy include specific instructions for constructing line , star, and ring infrastructure networks to optimize freight flow and alleviate urban congestion, extensive time and costs through empty running. And it should support public-private partnerships for infrastructure development and prioritize driver authentication , training and welfare programs to solve problem like theft, skill issues and lack of motivation of driver and improve road safety and prevent road accident. Significant infrastructure development is necessary to successfully operate a structured road freight transportation system. This involves building and renovating essential Rail corridors along major roads, creating well-equipped multimodal logistics parks, for seamless transfers between modes of transportation, and implementing these road networks to promote connectivity in both rural and urban areas.

Furthermore, standardized loading/unloading zones and parking facilities. There are 28 states and 8 union territories in India, interconnected with a huge road network infrastructure. In order to establish a structured and systematic transportation system, a network of girds is formed. These girds are the result of connecting line, ring and star network structures.

i. A line infrastructure network establishes a linear, two-way flow for goods or materials as shown in figure 3.3. It connects a District Warehouse Center (DWC) to both retailers, who receive a distributed goods, and suppliers, who provide materials for procurement. The simplicity of this network allows for easy integration with other intermodal transportation networks

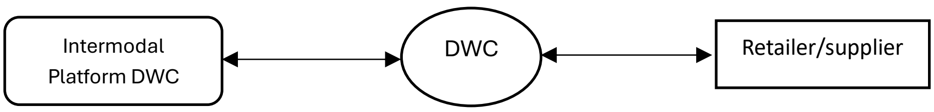

Fig. 3.3: Line infrastructure network

ii. A ring infrastructure network as shown from Figure 3.4, is constituted by DWCs situated in jurisdictions that are positioned along the periphery of the state. These DWCs are interlinked in a circular configuration to establish a closed-loop system. Consequently, it is Inter-district movement of commodities in the state and adjacent states can be executed with a high degree of efficiency.

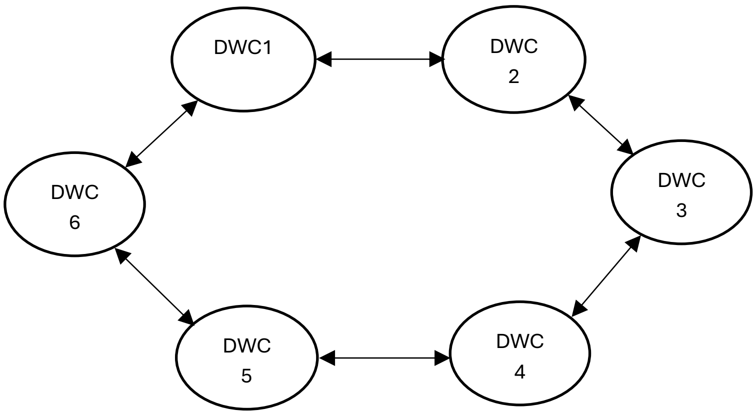

Fig. 3.4 : Ring infrastructure network

iii. A star infrastructure network as shown from Figure 3.5, it comprises all Railway Freight Terminals (RTF) located in district of the state are functioning as warehouse (hub) connected to multimodal logistics park via railways. At all railway goods shed terminals, a warehouse (hub) receive or distributes goods, from or to a network of DWC (spokes), resulting in numerous hub-and-spoke system designs.

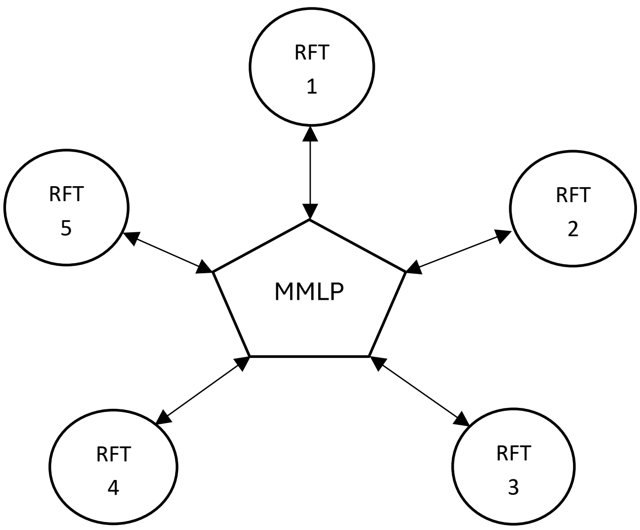

Fig. 3.5: Star infrastructure network

In the transit process where a company is undertaking a journey to DWC in a neighboring state, the transporter employs a combination of two networks, namely line and ring, in its route configuration. This approach is undertaken to ensure the efficient delivery of goods within a reduced timeframe and at a reduced cost. In the context of extensive distance travelled, such as the transportation of goods from the northern to southern regions of India, the incorporation of a line and star infrastructure network connecting DWC in one state to Indian freight trains, and subsequently to DWC in another state within a different state of India. This approach serves to mitigate the necessity for long-haulage trucks and corresponding costs , thereby reducing the overall expenses incurred by 3PL or 1PL companies during such protracted logistics processes.

3.2.4 1PL and 3PL in Logistics

First-Party Logistics is a model in which businesses manage their own transportation and distribution internally, ensuring full control but requiring substantial investments in infrastructure, personnel, and fleet management. This model framework is best suited for companies with extensive logistics expertise and the financial capacity to maintain an independent supply chain. They have their own private store to store the inventory, and when logistics department receives an order and details of consignment movement for transferring goods to DWC via a pertinent commercial vehicle. And in contrast, if the company chooses to outsource that is, 3PL for providing logistics functions, 3PL entities offering services to manage multiple logistics services for their clients as independent businesses separate from both the buyers and sellers. The sector consists of independent companies which assume part of the logistics tasks from both buyers and sellers. 3PL providers offer a range of services categorized into basic, value-added, and integrative. Basic service providers handle core functions like warehouse management, order processing, fulfillment, and selection of Local transporter which then contact truck owner for consignment. The Value-added service providers extend their offerings beyond basic functions by providing services such as shipment and order consolidation, which includes receiving orders and managing e-way bill details for consignment movement. These logistics integrators assume complete responsibility for essential supply chain operations. Their services include managing replenishment and order-filling and handling product returns.

3.2.5 Commercial vehicle selection

The employment of outdated vehicles with limited carrying capacity is one of the causes of India's road-based freight transport's inefficiencies. Small truck drivers in India are unable to purchase new, larger, and better trucks. To optimize utilisation of trucks by load matching . The given Table 3.4 guide for Vehicle selection for different network structures. Selecting the right commercial vehicle is shaped by a range of factors, with particular emphasis on the type of loading material and its weight, payload capacity, Fuel price / Per Unit Consumption Rate for EV, seasonality variation and geographical data of routes, Shipping method like FTL , LTL , PTL , where in FTL the entire truck is dedicated to a single shipment and in LTL, many shipments from different entities are combined to fill the entire truck and more cost-effective for smaller shipments but in PTL the trade-off is between FTL and LTL. This entails sharing a trailer with other clients without making additional stops for loading or unloading. Therefore, proper selection of goods carrier vehicle will reduce the number of trips the vehicle must travel to deliver the goods. Enhancing these selection procedures will lead to: A decrease in idle running Improved load factors and Increased use of vehicles.

Table 3.4: Guide for Vehicle selection for different infrastructure network

Structure type	Vehicles selection
Line network	LMV, containerised commercial Truck, L5N category Vehicle, N1 category vehicles.
Ring network	28ft /32ft containerised commercial Truck, containerised commercial Truck, HMV Transport Truck (T4)
Star network	22 ft HMV Transport Truck , 24-28 ft HMV Transport Truck commercial, containerised commercial Truck (N3).

3.3 Fuel Efficiency Optimisation

Fuel efficiency optimization and rational selection of suitable fuel types are of primary importance in reducing spending and environmental negative impacts reserved for road freight transportation. Fuel efficiency has greatly improved through innovations in vehicular technologies of optimised engine and lightweight materials like carbon fibre. Additionally, the integration of intelligent transportation systems and API of GIS software allows for making routes in real time to minimise unnecessary fuel costs and idle time.

The transition from traditional fossil fuels to alternative energy sources like biofuels (E20 and E100), compressed natural gas (CNG), flex fuel, electric batteries, and hydrogen fuel cell trains and trucks, which further cut down the carbon emissions. Long-haul freight can be operated through the use of E-fuels produced via renewable energy sources, with reduced emissions and compatibility with pre-existing infrastructure as shown in table 3.5.

Table 3.5: Fuel to cut down in the carbon emissions

Fuel Type	Carbon Emission Reduction Compared to Petrol/Diesel	References
E20 (20% Ethanol, 80% Petrol) / E 100 (100% ethanol)	17% - 80%	Suarez et al., (2024) , (Mohammed et al., 2021), Chaudhary & Subramanian, (2022)
CNG (Compressed Natural Gas)	20-25%	Rotaru et al., 2022), (Sun et al., 2024)
Electric Vehicles (EVs	60-100% (depends on electricity source)	Tetik Kollugil et al., (2024), (L. Zhang et al., (2025)

3.4 The Technological applications in cost reduction of road and rail freight transportation

To achieve real-time coordination and monitoring within India's road freight transport system, a multi-faceted technological approach is necessary. The following technological applications have been identified as key contributors to these line, ring, and star infrastructure networks , which will have discussed further in this section.

3.4.1 Transport Management System (TMS)

An enterprise transportation management system serves as application program that helps companies organize logistics operations starting from the shipment origin until delivery at final destinations while maximizing operational efficiency. The system provides with complete supply chain oversight which helps you optimize operations with dispatch generation for road transportation while improving stakeholder partnerships and enhancing critical decision-making processes. TMS enables optimised route planning, significantly reducing transportation costs and delivery times.

Enhanced collaboration is attained by merging with ERP and WMS to boost stock control and order completion. Modern TMS solutions utilise mobile and web interfaces for real-time tracking by lorry receipt number, GPS, etc. and fleet management of , enhancing user experience as discussed by Emek et al., (2024). Automation of processes minimises manual errors and enhances decision-making capabilities, leading to improved operational performance as discussed by Quiroga-Amaya et al., (2024).

Transportation management systems provide enhanced features and functionalities, such as load consolidation, which maximises container utilisation and lowers transportation costs by merging multiple orders into a single shipment. Additionally, they offer reporting and analytics, allowing access to comprehensive dashboards and reports for insights into transportation costs, key performance indicators, and trends. Automate documentation and enhance security through digital proof of delivery (POD) and electronic logging devices (ELD). The adoption of cloud-based TMS solutions has further improved scalability, accessibility, and cost efficiency, allowing organisations of all sizes to optimise their transportation networks. Ultimately, a well-implemented TMS contributes to a more resilient, cost-effective.

3.4.2 The Internet of Things (IoT) integration in road and rail freight transportation

Cargo transportation utilizing road and rail infrastructure is witnessing the advent of a new transformative technology, the IoT, which promises to maximise operational efficiency while providing instantaneous data tracking and optimized managerial responses and cloud based fleet management. Among the domains where IoT applications are prevalent, we focus on bringing vehicles, cargo, and infrastructure together through a network various sensors and devices are employed to gather, analyse, and transmit data. Telematics systems in vehicles enable remote diagnostics by identifying potential malfunctions or faults and these on-board diagnostics systems 2 (OBD-2) as discussed by Chen et al., (2011) and also discussed that IoT technologies employed to acquire real-time operational data from vehicles and status of various vehicle subsystem. OBD-2 when a problem is detected, the vehicle's computer stores a Diagnostic Trouble Codes , which is a code that identifies the particular problem is identified, and the vehicle data is transmitted to cloud-based platforms, where it is analysed to produce notification and recommend appropriate corrective measures. IoT enables real-time monitoring of shipment, vehicle performance and predictive maintenance to eliminate delays and minimising costs. The shipment monitoring enable the observation and assessment of internal container conditions by using sensors like temperature , pressure , humidity, light, accelerometer, gyroscope motion, tilt, etc. IoT devices can also be used to improve safety in trucking and freight train operations by keeping track of driver activity, behaviour, health or conditions to ascertain whether something is amiss and recommend solutions to prevent an accident and enabling automated safety features such as collision avoidance. The Advance Driver Assistance System level 3 (ADAS -3) could be considered a cutting-edge solution that is tailored specifically for heavy commercial vehicles, meeting the demands of long-haul trucks by providing conditional automation. The Use of RFID in Indian railways Tagging in Wagons and Coaches for Identification and Tracking/Tracing of Assets. Additionally, real-time location tracking of a transportation fleet system uses GPS technology is utilized to monitor the real-time location of a vehicle and to generate timely alerts send to manager in case of deviation in planned routes, so that remedial action can be taken. The research notes that the IoT devices and cloud based services can further enhance the capabilities of cargo vehicles, allowing for cooperative data sharing and real-time updates on vehicle or freight train status and cargo conditions to its stakeholders. Therefore, leads to decreased transit time, accidents and costs in freight transportation.

3.4.3 AI integration in road and rail freight transportation

In recent years, artificial intelligence have been integrated Within the domain of road and the transport of cargo by rail as a subject of great interest. Artificial Intelligence (AI) will completely transform road and rail freight transportation. They are developed to predictive maintenance, route planning, demand forecasting and autonomous trucks and trains. The Dynamic route planning based on current traffic conditions, time of day, weather, fuel stations, toll plaza, road congestion levels, even historical traffic patterns and delivery schedules, is possible by Multi-Agent Reinforcement Learning or Reinforcement learning (RL) as discussed by Qin et al., (2019). RL-based routing in congested networks significantly improves efficiency compared to shortest-path methods, particularly in dynamic traffic conditions to minimise fuel consumption and corresponding cost and generation of alternate routes study by Cox et al., (2013). Predictive maintenance powered by AI tools leveraging Supervised and unsupervised learning-based methods are available for analysing large datasets collected from vehicle telematics and historical performance metrics to determine when maintenance is needed for a vehicle by assessing sensor data, minimising downtime and breakdown thus extending vehicle lifespan and operational time. Furthermore, Computer vision stands as a revolutionary technology within road and rail freight operations that delivers innovative methods to boost operational effectiveness while protecting safety and reducing environmental impacts. The CV systems for road freight is used to detect vehicle around it, then analyse driver actions together in real time to minimise accidents while protecting freight cargo from damage. The implementation of CV delivers important rail freight benefits through Computer vision systems that monitor the condition of train wheels and tracks in real-time, identifying defects like cracks or missing bolts and anomaly detection capabilities. By automating the inspection process, computer vision reduces the need for manual checks, speeding up operations and reducing downtime. This helps to prevent derailments and ensures the safety of rail operations, which both raise operational stability and lower maintenance expenditures. Now research by Bahga & Madisetti, (2013) revels that implementation of AI in shipment monitoring is the analysis and interpretation of data on the environment conditions in the container for Frozen, Refrigerated Perishable goods truck, where alerts can be raised to the driver and the distributor about the transit conditions , such as container temperature and humidity levels going out of the allowed limit, for instance corrective actions can be taking before damaged, using the AI which is applying Autoencoders , Isolation Forest algorithm as discussed by Neloy & Turgeon, (2024) and Reinforcement Learning ML model. Overall, integrating AI into freight transportation not only modernizes transport in logistics but also sets a new standard for efficiency and customer satisfaction in the industry. The fig 3.2: showing the formation of AI system for road and rail freight transportation.

3.4.4 Unified Logistics Interface Platform (ULIP)

India's freight system is unregulated and unstructured. Currently, in India, many logistics companies(3PL) don’t own any commercial vehicles that can be used to transport goods or cargo of manufacturers, or producers from one place to another. Subsequently, these logistics companies have contracts with freight forwarding vendors and agencies which have partnerships with regional transporters. These regional or local transporter then have some truck owners working with them. These truck owners don’t have any links to logistics companies. There can be the chances of truckload theft thus causing huge losses to manufacturers and distributors. Lack of Real-time information and tracking of cargo trucks can decrease the efficiency of operations. In India, 5% of companies like DHL, etc. have their own trucking services hence having structured logistics systems. But the remaining 95% of companies don’t have a standard approach and run their transportation system in an unstructured manner. So, ULIP is the solution to these problems. The Unified Logistics Interface Platform is a combined platform for data communication among government and private institutions that are directly or indirectly associated with the Indian Logistics ecosystem and reduce the cost of logistics in India. It is democratizing information available with various Govt. systems for a transparent and competitive Logistics ecosystem. It is API based data exchange between the stakeholders to enable innovative approaches in improving India's Logistics sector. ULIP is utilized to develop a nationwide integrated logistics network for total visibility and optimal deployment of different transport modes and supply data that can be harnessed by the stakeholders for easing complex tasks like compliance, paperwork, certifications, and endorsements, which were usually time-consuming, difficult to manage appropriately, and needed to track consignment on multiple portals. So, with ULIP all the information like Shipping Bill, Railways FNR, Airway Bill, LR, E-way Bill, etc. is presented on single window of ULIP. There is always difficulty in manual verification of drivers & vehicles by manufacturers or distributors and without ULIP, the increased risk of non-compliant transportation can lead to serious consequences, including hefty fines, delayed delivery, and seizure of goods. Therefore, ULIP will instantly verify commercial vehicles and help increase productivity, efficiency, and effective movement of goods and reduce logistics costs & time. Currently, the platform integrates with 43 systems from 11 ministries via 129 APIs, covering over 1800 data fields. Another platform contained in ULIP is the Logistics Data Bank (LDB). LDB operates as a tracking system that monitors the movement of containers from ports to their different hinterland locations which include ICD, toll plazas, railway stations, both during domestic and international movements. Real-time tracking through IoT and Big Data and Cloud-based solutions. As a cloud-based logistics tracking system it functions as a single visualisation platform where users can track containers through their identification numbers. Furthermore, one important aspect of ULIP is FOIS which provides consumers with convenience, speed, and ease by allowing them to register and book indents for rakes and waggons online. It can track and monitor the movements of goods trains. The information is subsequently published to end users via ULIP. It has now evolved into a comprehensive goods train management module that can handle billing and revenue collection. It has contributed significantly to increased waggon productivity on Indian Railways, and the goal is to use the data to boost productivity and customer service even further, meeting the needs of a rapidly rising economy. The ULIP Can be connected to existing transportation management systems of the logistics company so that real time information of their transit goods and transporter can be shared easily. Thus, increase transparency and visibility in the entire fleet management to reduce empty movement and waiting time.

3.5 Intelligent freight transportation system

The Intelligent freight transportation system’s architecture in Fig. 3.6 operates through a multi-layered, data-driven framework that integrates various stakeholders, digital systems, and logistics applications to enhance efficiency, security, and transparency across multimodal transport infrastructure networks. This platform functions as a virtual gateway, serving both as a conduit for exchanging data and as a central hub for managing transportation and supply chain processes. The process flow begins with, at the highest level, a collection of governmental and regulatory systems and various national agencies connected to a unified logistics platform.

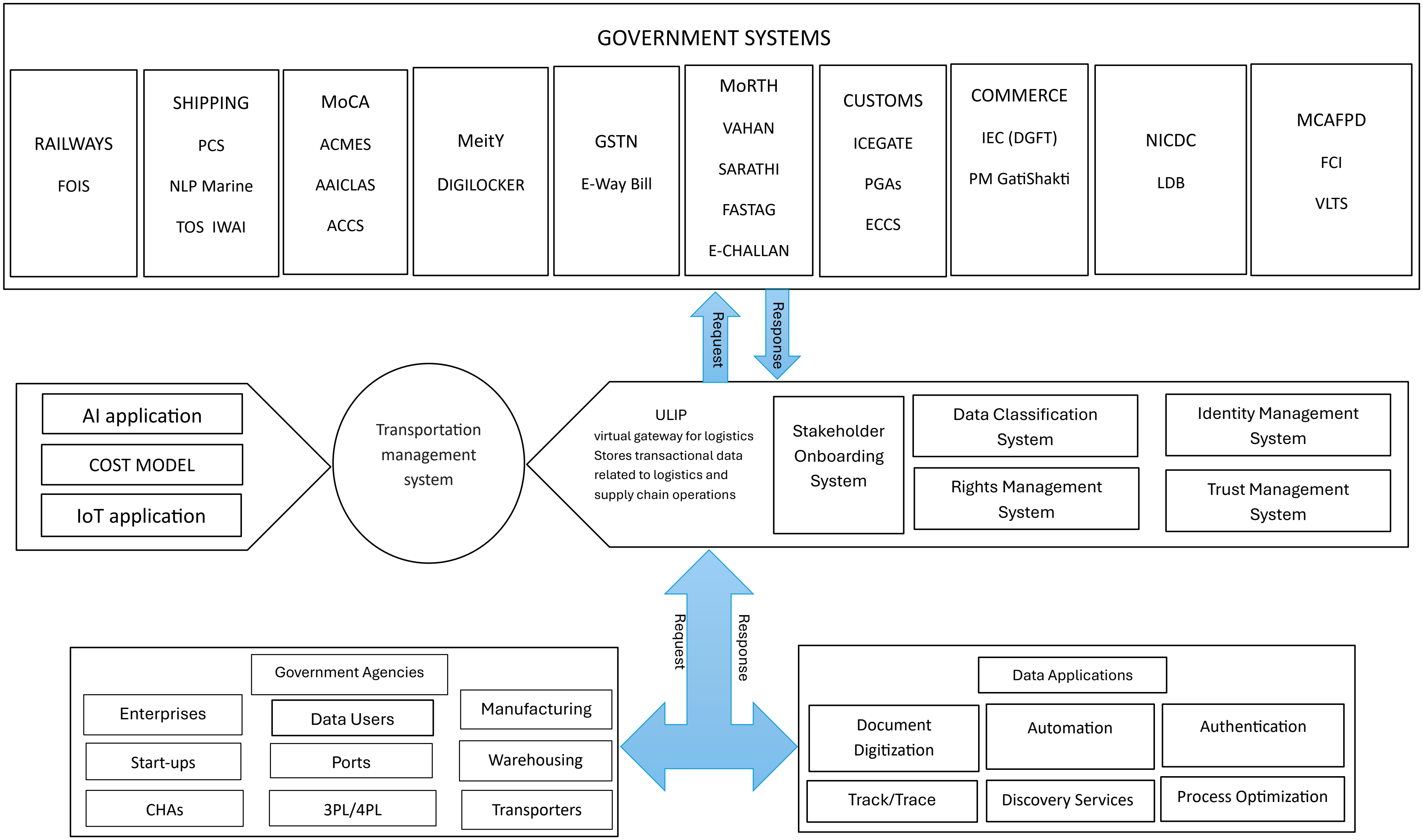

Fig. 3.6: Architecture of Intelligent freight transportation system

The private stakeholders (e.g., third-party logistics providers, warehouses, and transporters) have to sign in to ULIP and then receives this data and channels it into different subsystems: a Stakeholder Onboarding System, which authenticates and registers new participants in a Data Classification System, which organises the data into structured formats; and an Identity Management System, which ensures secure handling of user identities and credentials. In tandem, a Rights Management System and a Trust Management System govern data access and usage permissions, preventing unauthorised access while maintaining a reliable environment for data exchange. Within the platform, the stakeholder requests information and certification in real time and then gets a response from government agencies and other data users.

IFTS supported from AI applications, IoT applications, and the cost model applications through (Application Programming Interface) APIs in TMS, which will integrated into the logistical framework, enabling users to calculate transportation costs under various scenarios. Other functionality of ULIP such as document flow, track/trace of cargo vehicle, and authentication services will be performed. The overall outcome is a coordinated and digitalised logistics environment that standardises information exchange, planning fleet journey, transport cost calculations, and streamlines procedures for various government agencies, logistics providers.

3.6 COST MODEL DEVELOPMENT

The predominant approach employed by the 1PL company and 3PL freight forwarder to accomplish transport assignments involves the utilisation of bottom-up estimating. The Bottom-up estimating in road and rail transportation involves detailed analysis and modelling to achieve accurate cost predictions. It consists of breaking down the transportation process to the lowest level, which is fixed, variable costs and Miscellaneous Costs (the smallest component), and then aggregating all related costs by calculating the cost of each component and then adding them to find the overall cost of transportation in transit. As illustrated in Table 3.6, These costs is incurred by logistics companies when they undertake freight transport. The subsequent three cases illustrate the development and implementation of the cost model framework.

Table 3.6: Costs associated with road and rail freight transportation

Fixed costs	**Variable costs**	**Miscellaneous Costs**
Cargo vehicle's driver salary per trip d	Driver Allowances e	Indian Railway Indent Booking charges B
Support staff salary d_S	Fuel cost F	Accident Costs ε
contract driver wages per trip d_e	Cargo insurance C_i	Transporter margin % γ
Lease carrier vehicle Cost V	Terminal handing charges per trip t_h at Railway freight terminal	
Administrative charges per trip x	Total Loading/unloading Labour Costs per trip C_H	
Container Cost per trip C_C	Warehousing charges for storing q	
GST G	Packaging cost ω	
Spare part cost of cargo vehicle s	Parking Cost per trip P	
	Maintenance & repair Cost M	
	Total toll charges per trip T	
	Special Handling Charges ∂	

The primary units used to measure goods in road freight transport are tonne-kilometer (tkm) and the Road-Rail freight transport rate having unit Rupees per metric ton kilometer as discussed by Heizer, J., Render, B., Munson, C, (2020) The breakdown of cost components is respectively stated below.

- Total cost of transportation C_T
- Total Fixed cost C_F
- Total variable cost C_v
- Distance travelled D in km
- Type of fuel f_T
- Mileage m varies with types of fuel , type of Truck and uses condition
- Packaging cost can be considered per tonne, per pallets or per box.
- Terminal handling charges can be considered per tonne or per pallets
- Warehousing charges can be considered per cubic foot or per pallets
- Weight of goods W in Tonne
- Transit time t
- Cargo insurance is quantity dependent variable C_i
- Fuel cost , $F = f \times \frac{D}{m}$; fuel price / liter = f
- Number of Trips N

- Cost of Cargo Handing per trip is calculated as:

$$C_H = \sum_{k=1}^{n} c_{hk}$$

where, k Where is the number of warehouses in which unloading and loading of goods are performed during a trip and c_{hk} is the loading and unloading labours charges per 100 kg or box at warehouse.

- $\text{Revenue} = \text{Road Freight Transport Rate} \times \text{Distance (km)} \times \text{Total weight of load (tons)} \times \text{Number of Trips} \times \left(1 + \frac{Transporter\ margin}{100}\right)$

$$\text{Revenue in any network} = C \times D \times W \times N \times \left(1 + \frac{\gamma}{100}\right) - \varepsilon$$

$$\text{Road Freight Transport Rate in any network} = C$$

3.6.1 Application of the line infrastructure network within a limited region in Delhi

In the context of a hypothetical transport enterprise (3PL or 1PL) operating in the proposed structured Road-Rail freight transportation system. One can envisage a particular scenario whereby the logistics company is engaged in the transportation operation with line infrastructure network, this can be applicable across any transport activities conducted between the DWC and the Multi-Modal Logistics Park located , or alternatively, from the DWC to the retail outlet. The line infrastructure network works best in FTL Shipment. The journey commencing from an Inland Container Depot located in Tughlakabad within the jurisdiction of Southeast Delhi district, and concluding at a retailer situated in the Chhatarpur area of the southern segment of Delhi district as shown in fig 3.7. The driver is equipped with Intelligent freight transportation system, which can provide navigation application such as NaviMaps or any Geographic information system (GIS) application link by API, that is adept at providing the most efficient routes along with the estimated time required to reach the designated destination, fuel station , traffic condition in real time. Upon the delivery of the load by the transporter at either the retailer or the DWC, the relevant confirmation details are updated for all relevant stakeholders via ULIP.

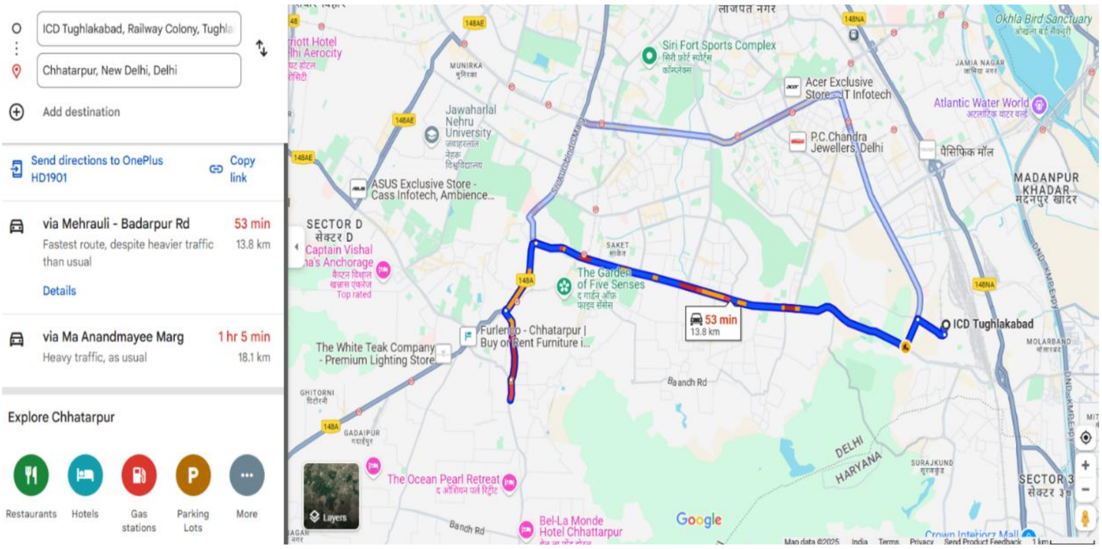

Fig. 3.7: Line infrastructure network within a limited region in Delhi (source: google maps)

The logistics company can accept the empty run cost, but if it delivers the load at DWC/MMLP, then the transporter can get the load for the return trip through TMS and ULIP , resulting in a profit. So Presented below is the cost estimation that pertain to a line infrastructure network of cost model application. It is essential to note that there are no toll plazas situated along the designated short transport route, but longer route may have toll plaza. Thus, in this case toll charges is not applicable when calculating the total operational cost associated with this transportation endeavor. Hence, we can compute the entire cost of transportation in the line network per trip using the following equations as discussed by Heizer, J., Render, B., Munson, C, (2020):

Total cost in line infrastructure network C_{Tl}
Fixed cost in line infrastructure network C_{Fl}
Total variable cost in line infrastructure network C_{vl}
Empty run cost in line infrastructure network during return journey $C_{el} = F + M$
Transporter margin % γ

i. own vehicles with own drivers

$$C_{Tl} = C_{Fl} + C_{vl} + C_{el}$$

$$= [d + d_S + C_C + G + s + x] + [F + e + P + C_H + C_i + \omega + t_h + M + q + \partial] + C_{el}$$

ii. Rented vehicle with external driver (outsourcing)

$$C_{Tl} = C_{Fl} + C_{vl}$$

$$= [V + d_e + C_C + G + s + x] + [F + e + C_H + C_i + \omega + t_h + M + P + q + \partial]$$

iii. Road Freight Transport Rate in line infrastructure network , $C_L = \frac{C_{Tl}}{W \times D}$ in Rupees per ton per Kilometer

iv. Revenue in line network $= C_L \times D \times W \times N \times \left(1 + \frac{\gamma}{100}\right) - \varepsilon$

The equation (i) gives the total cost in rupees per trip when operated in a line infrastructure network for the 1PL and 3PL companies that have their own vehicles with their own drivers. But the equation (ii) provides the total cost in rupees per trip when operated in a line infrastructure network for the 1PL and 3PL companies that have their rented vehicles with external drivers, which means these companies hired the local transporters for the transportation process . The equation (iii) provide the Road Freight Transport Rate in Rupees per Ton per Kilometer. Through equation (iv), one can ascertain the revenue accrued throughout the entire journey of a shipment of goods, commencing from point of starting to the last delivery location within the line infrastructure network.

3.6.2 Application of the Ring infrastructure network in Delhi

In reference to the ring infrastructure network, which will be strategically established by creating a DWC in each Legislative Assembly constituency (AC) that is in close proximity to the borders of Delhi's state territory, as it can be seen in Figure 3.8, this encompasses the Assembly Constituencies namely AC-1, AC-7, AC-8, AC-35, AC-34, AC-36, AC-45, AC-46, AC-52, AC-53, AC-54, AC-56, AC-62, AC-68,AC-70 and AC-2. The selection of these particular locations was meticulously determined based on the potential for enhanced strategic business opportunities that could arise in conjunction with neighbouring states. Regarding these DWCs, the cargo vehicles are capable of transporting goods to various other states or conversely, bringing goods from other states to Delhi, all in a well-structured manner that minimizes costs significantly. In the context of a hypothetical transport enterprise (3PL or 1PL) operating in the proposed structured Road freight transportation system. One can envisage a particular scenario whereby the logistics company is engaged in the transportation operation with Ring infrastructure network through the Intelligent freight transportation system. The Ring infrastructure network is suitable for LTL Shipment and there are frequent truck loading and unloading stoppages at various DWCs in the ring infrastructure network. The corresponding confirmation details of all delivery and pickup points are updated for all respective stakeholders via ULIP. Because the vehicle makes many stops, this case allows for more flexibility in shipping schedules, including last-minute or unexpected shipments. Furthermore, every stakeholder can Track/Trace and authenticate their fleet process easily with ULIP. it is imperative to recognize that toll plazas may be located along the planned transportation route. Relevant data regarding these toll facilities can be procured from the TMS and ULIP platform of Intelligent freight transportation system. Consequently, when goods are transported to nearby states, toll charges and increased handling fees must be incorporated into the overall calculation of Toal costs. Hence, we can compute the entire cost of transportation in the Ring infrastructure network per trip using the following equations as discussed by Heizer, J., Render, B., Munson, C, (2020):

Total cost of transportation in ring infrastructure network C_{Tr}
Fixed cost in ring infrastructure network C_{Fr}
Total variable cost in ring infrastructure network C_{vr}
Empty run cost in ring infrastructure network $C_{er} = F + M + T$
Transporter margin % γ

i. Own vehicles with own drivers

$$C_{Tr} = C_{Fr} + C_{vr} + C_{er}$$
$$= [d + d_S + C_C + G + s + x] + [F + P + C_H + T + e + C_i + \omega + q + M + y + \partial] + C_{er}$$

ii. Rented vehicle with external driver

$$C_{Tr} = C_{Fr} + C_{vr}$$
$$= [V + d_e + C_C + G + s + x] + [F + C_H + e + C_i + \omega + T + M + P + q + \partial]$$

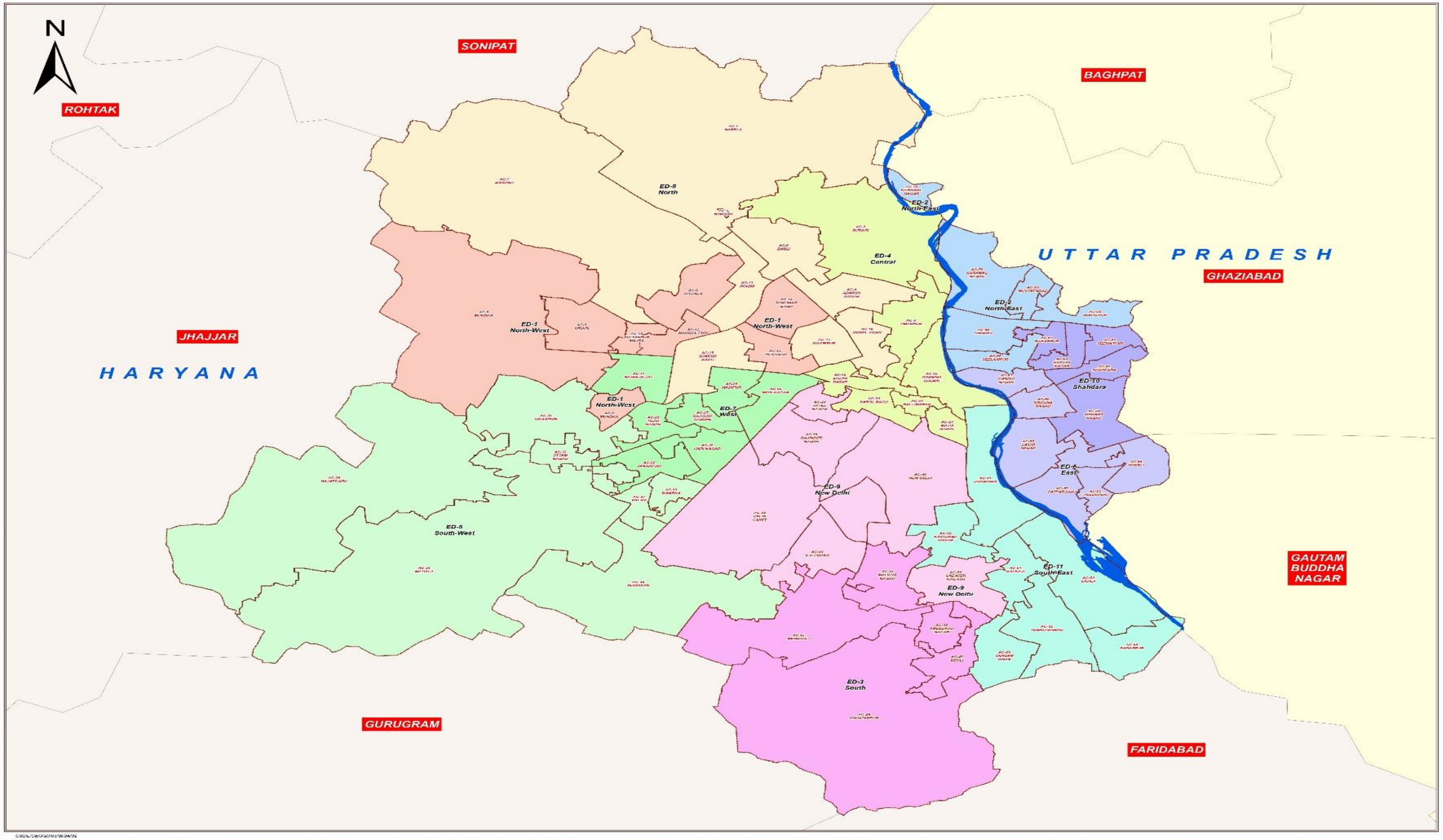

Fig. 3.8: Map Of Delhi's District with Assembly constituency at Delhi's boundary forming Ring infrastructure network (source: https://dmnewdelhi.delhi.gov.in/map-of-district/)

iii. Road Freight Transport Rate in ring infrastructure network , $C_r = \frac{C_{Tr}}{W \times D}$ in Rupees per ton per Kilometer

iv. Revenue in ring network $= C_r \times D \times W \times N \times \left(1 + \frac{\gamma}{100}\right) - \varepsilon$

The equation (i) delineates the comprehensive cost expressed in rupees per trip when executed within the ring network for both 1PL and 3PL enterprises that possess their own vehicles and employ their own drivers. Conversely, the equation (ii) articulates the comprehensive cost in rupees per trip when conducted within the ring network for the 1PL and 3PL enterprises. The equation (iii) provide the Road Freight Transport Rate in Rupees per Ton per Kilometer of ring network. And the equation (iv) can be used to calculate the revenue generated during the complete journey of goods from its origin point to its final delivered location within the state and neighbouring state, in ring network.

3.6.3 Application of the Star infrastructure network within NCR Delhi

In the context of a hypothetical transport enterprise (3PL or 1PL) operating in the proposed structured Road-Rail freight transportation system. One can envisage a particular scenario whereby the logistics company is engaged in the transportation operation with star infrastructure network through the Intelligent freight transportation system. The star infrastructure network is suitable for PTL and FTL shipping methods. In our planning efforts, as seen in Fig 3.9, the Delhi railway map, which is mainly considered for making MMLP and goods shed. we posit that the establishment of the Multimodal Logistics Park (MMLP) will take place at the strategically significant Hazrat Nizamuddin Railway Station, which is located within the bustling metropolis center of Delhi. Moreover, this site is in close proximity to the banks of the Yamuna River, thereby enabling the potential for the utilization of inland water transport (IWT) as a viable means of logistics. we have meticulously designed a star infrastructure network that encompasses all District Warehouses and Centers (DWCs) situated at the Railway Freight Terminals within the state known as RFT , with these facilities being intricately linked to a central hub or multimodal logistics park through an extensive network of railways , particularly as this system is also directly integrated with the FOIS online portal service in ULIP and Intelligent freight transportation system. Consequently, the transition of bulk or long-haul freight operations to rail transportation has the capacity to significantly diminish the overall fuel consumption associated with the road freight transport. For the operators of road freight services, the reduction of congestion on roadways yields a notable decrease in idle time, which in turn results in lower emissions and reduced fuel expenditures. The road freight transport serves an major function during first mile of the logistics chain by facilitating the movement of goods to and from these strategically located RFT hubs. For instance, there exists a particular goods-carrying truck that originates from DWC, the DLF Kirti Nagar Industrial Area, which is located in the Northwest District of Delhi, and this truck is making its way towards the SSB (SHAKURBASTI) Railway goods shed terminal (RFT) with the intention of transferring various goods onto a freight train. This transfer is essential as it allows the aforementioned freight train to subsequently transport the goods to the MMLP, which is strategically situated at the Hazrat Nizamuddin Railway Terminal. Thus, Indian Railways' dedicated freight corridors is utilised to reach the destination Railway goods shed terminals or MMLP. This entire process is coordinated by FOIS online portal where the company booked a wagon or rake as per their need and paid the Indian Railway Indent Booking charges. Then the unloading the load from cargo container and load it into truck for delivering to DWC in the Other states of India using Line infrastructure network. This allows items to reach at their destinations at far lower prices and in much less time and carbon emission than traditional road transit techniques. In the context of the star infrastructure network, it is essential to note that there are no toll plazas situated along the designated short transport route within the state, and this critical information can be sourced from the ULIP. Thus, in this case toll charges is not applicable when calculating the total operational cost associated with this case.

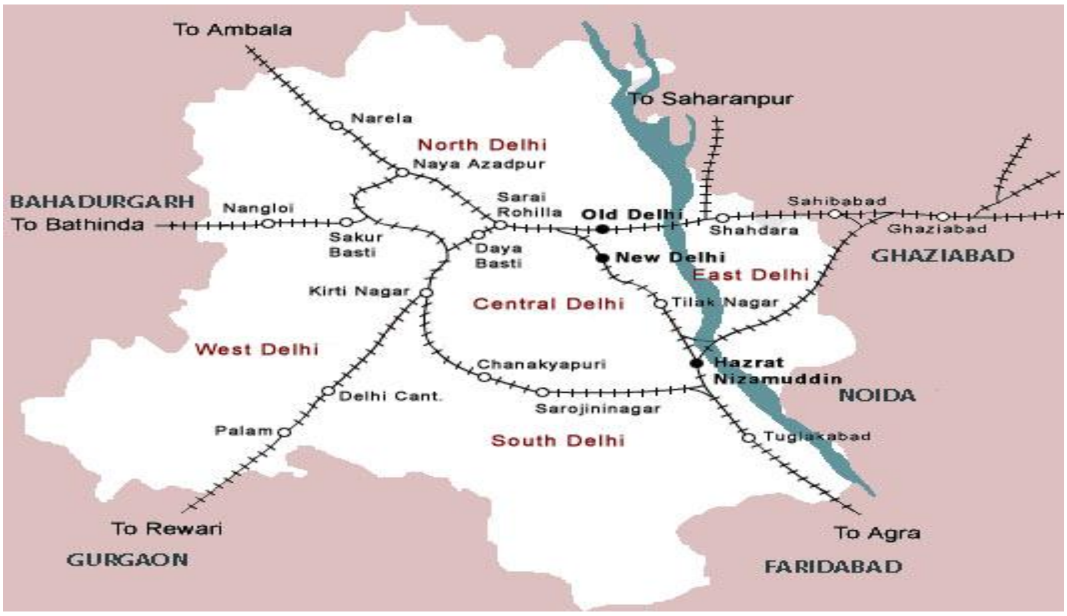

Fig. 3.9: Indian Railways network in Delhi NCR (source: https://www.mapsofindia.com/maps/delhi/railway.html)

Hence, we can compute the entire cost of transportation in the star infrastructure network per trip using the following equations as discussed by Heizer, J., Render, B., Munson, C, (2020):

Total cost of transportation in star infrastructure network C_{Ts}
Fixed cost in star infrastructure network C_{Fs}
Total variable cost C_{vs}
Empty run cost in Star infrastructure network $C_{es} = F + M$
Transporter margin % γ

i. own vehicles with own drivers

$$C_{Ts} = C_{Fs} + C_{vs} + B + C_{es}$$
$$= [\, d + d_S + C_C + G + s + x \,] + [\, F + P + e + C_H + C_i + \omega + t_h + \partial + M \,] + B + C_{es}$$

ii. Rented vehicle with external driver

$$C_{Ts} = C_{Fs} + C_{vs} + B$$
$$= [\, V + d_S + d_e + C_C + G + s + x \,] + [\, e + F + C_H + C_i + \omega + t_h + M + P + q + \partial] + B$$

iii. Road-Rail Freight Transport Rate in star infrastructure network , $C_s = \frac{C_{Ts}}{W \times D}$ in Rupees per Ton per Kilometer

iv. Revenue in star network $= C_s \times D \times W \times N \times \left(1 + \frac{\gamma}{100}\right) - \varepsilon$

For the last case, the equation (i) provides the expenditure in rupees per trip when functioning within a star infrastructure network for both 1PL and 3PL entities that possess their own vehicles along with designated drivers for road cargo transport vehicles to reach RFT or MMLP , and when the goods are transferred to respective freight trains, the rail transportation costs associated with carrying the goods to the destination, which is paid by these companies to Indian Railways of the Govt. of India are added in it. Conversely, the equation (ii) elucidates the total expenditure in rupees per trip when operating in a star infrastructure network and both 1PL and 3PL entities utilise rented vehicles with external drivers for road cargo transport vehicles to deliver the goods to RFT, and from there the load or goods are transferred to freight trains so the rail freight transportation costs associated with carrying the goods to the destination, which is paid by these companies to the Indian Railways of the Govt. of India, are added in it. The equation (iii) provide the Road Freight Transport Rate in Rupees per Ton per Kilometer. And the equation (iv) is able to ascertain the revenue accrued throughout the entirety of a shipment's journey, commencing from its starting point to its final stop in another state of India.

3.7 Comparison between star infrastructure network and ring infrastructure network

The star and ring infrastructure networks are two fundamental models in the framework of freight transportation systems. Each network has unique structural, operational, and economic characteristics that influence its suitability for different freight logistics scenarios. The table 3.7 shows the comparison of star infrastructure network and ring infrastructure network that can be tabulated around several key features.

Table 3.6: Comparison of star infrastructure network and ring infrastructure network

Feature	Star ring infrastructure networks	Ring infrastructure networks
Network structure	Central MMLP connects all RFTs	Each DWC at peripheral of the connects to two adjacent DWCs forming a closed loop
Modes	HMV, LMV vehicle and Railway freight train	HMV, LMV, L5N and N1 vehicles
Shipment method	FTL and PTL shipment	Less than truck load (LTL) shipment
Efficiency	Enables economies of scale in transport due to high volume of load and efficient for long-haul freight transportation	Efficient of freight transportation within a state
Cost Implications	Lower if existing structure are arranged in proposed star infrastructure network but High capital investment for new MMLP	Minimal capital allocation for the advancement of new roadway construction in alignment with the ring infrastructure framework.
Management	Centralized control and coordination can simplify overall network management from a strategic perspective	Coordination becomes complex with increasing numbers of DWC or if dynamic routing/scheduling is required across the ring network
Transit Time	Longer time due to larger distance and potential processing delays	Less time as distance travelled is least and within a states.

CHAPTER 4

IMPLEMENTATION, RESULTS AND DISCUSSION

4.1 Implementation- star infrastructure network

In an extensive analysis regarding the considerable distances traversed, particularly exemplified by the intricate logistics involved in the transportation of goods originating from the northern regions of India that is Delhi and destined for the southern territories, that is Indore , a sophisticated strategy is proposed that entails the implementation of a star infrastructure network with the help of the logistic company This infrastructure network, which effectively links the Distribution Warehousing Centers (DWC) situated in one state to the extensive network of Indian freight train, subsequently facilitates a seamless connection to the DWC located in another state within the diverse geographic and economic landscape of India. Such a method not only serves to significantly alleviate the dependence on long-haul trucks, which are often associated with exorbitant operational costs, but it contributes to diminishing the overall financial burdens that are typically borne by 3PL or 1PL companies involved in the management of these extended and complex logistics processes. Following the implementation of the aforementioned cost model in star infrastructure network , by the logistics company generated the below mentioned data, The table 4.1 shows the total cost (in rupees) and Road-Rail freight transport rate (Rupees per Ton per Kilometer) of Long-haul freight transportation between Delhi to Indore. The figure 4.1 demonstrates the Movement of goods in employing star infrastructure network. A comprehensive evaluation and comparative analysis of the cost implications associated with traditional long-haul road freight transportation methods versus the innovative star network approach is meticulously undertaken, employing the sophisticated analytical capabilities of the SPSS software tool to enhance the validity of the result. A flowchart depicting the Computation procedure is shown in Figure 4.2.

Fig. 4.1: Movement of goods in employing star infrastructure network

Table 4.1: Total freight transport cost between Delhi to Indore

Own vehicles with own drivers (star network)		Rented vehicle with external drivers (star network)		Long-haul freight transportation with trucks	
Total cost	Road-Rail Freight Transport Rate	Total cost	Road-Rail Freight Transport Rate	Total cost	Road-Rail Freight Transport Rate
₹ 67,850	5.874	₹ 68,650	5.944	₹ 80,640	7.982
₹ 65,300	5.654	₹ 65,325	5.656	₹ 74,650	7.463
₹ 66,470	5.755	₹ 65,820	5.699	₹ 79,350	6.870
₹ 68,900	5.965	₹ 69,732	6.037	₹ 75,000	6.994
₹ 70,450	6.100	₹ 72,650	6.290	₹ 85,000	7.359
₹ 66,750	5.779	₹ 71,300	6.173	₹ 90,050	8.797
₹ 71,200	6.165	₹ 65,930	5.708	₹ 89,200	7.723
₹ 66,300	5.740	₹ 66,410	5.750	₹ 89,000	7.706
₹ 65,600	5.680	₹ 66,522	5.759	₹ 76,000	7.580
₹ 67,000	5.801	₹ 67,450	5.840	₹ 79,400	6.974

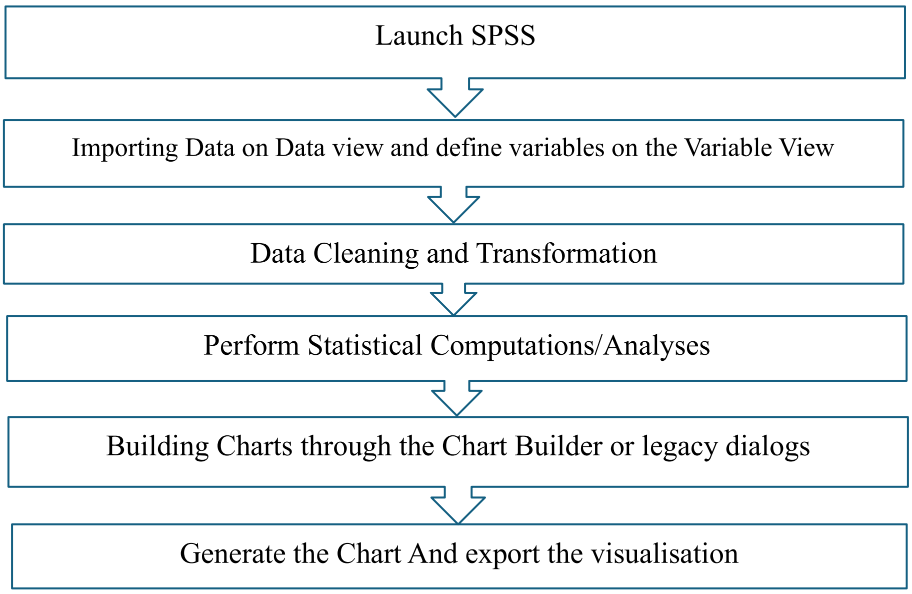

Fig. 4.2: flowchart depicting the Computation procedure in SPSS

4.2 Results

The comparison of the overall cost of transportation for Long-haul freight transport involving heavy-duty trucks following the traditional unstructured approach and using roadway in contrast to the innovative star network integrated with bottom-up cost estimating model within Intelligent freight transportation system that has been proposed for more effective cost assessment in this domain where it results in total transportation expenditures diminish by 17 to 20%. And the variability is least in own vehicle own driver ownership scenario, as shown in figure 4.3

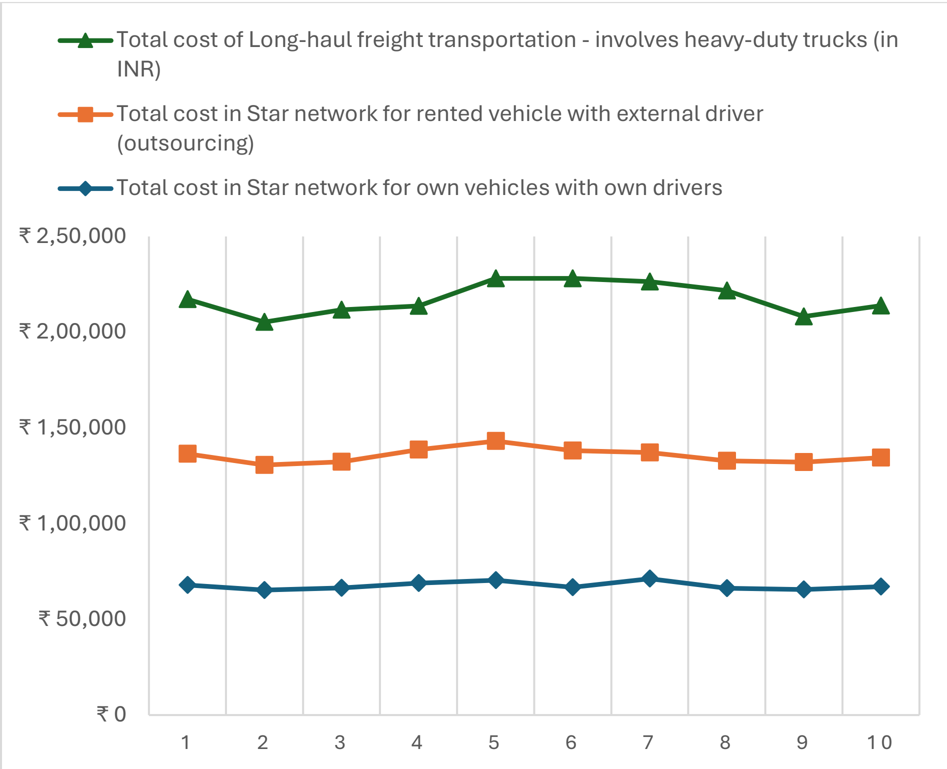

Fig. 4.3: Total transport cost (in rupees)

The figure 4.4 show the comparative analysis of the transport rate of OVOD, RVED in star network and long-haul road freight transportation. It is found that own vehicle own driver ownership scenario result in the lowest cost expense of freight transport rate. That is, the cost per metric tonne per kilometre ranges from 4.5 to 5.8 rupees , which is lesser than long-haul road freight transportation.

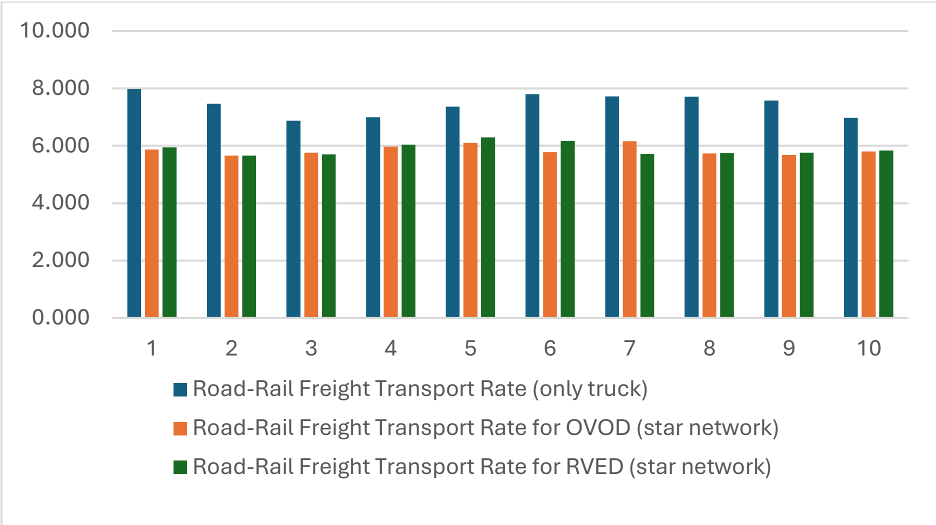

Fig. 4.4: Road-Rail Freight Transport Rate (Rs. per metric tonne kilometer)

4.3 Discussion

Based on the result of the application of the star infrastructure network using IFTS for long-haul freight transportation. The research successfully establishes a comprehensive and modular framework for estimating road-rail total expenditures of freight transport in India. The cost model decomposes the total cost into three infrastructure networks. The line infrastructure network establishes a linear, two-way flow for goods or materials; the ring infrastructure network, where DWCs are interlinked in a circular configuration to establish a closed-loop system allowing inter-district movement of commodities in the state and adjacent states in the least time at the lowest cost; and the third network, which is not specified. And the star infrastructure network in star topology that comprises all Railway Freight Terminals (RTF) located in districts of the state connected to multimodal logistics parks via railways and performs efficiently for long-haul transportation. Dynamic pricing strategies were examined in relation to factors such as fuel price volatility, seasonal demand fluctuations, road conditions, and policy interventions. A crucial aspect of these network-specific models is their explicit accounting for the heterogeneity of the Indian road freight sector. The IFTS, underpinned by ULIP, AI, and IoT, was analysed for its transformative potential. AI-enabled predictive analytics were found to be particularly beneficial in demand forecasting and dynamic route planning. IoT devices such as GPS trackers, RFID tags, and telematics systems enhanced the reliability of operations, further supporting cost reduction through preventive maintenance and fuel efficiency optimisation. The examination of the comprehensive transportation expenses and the corresponding charges in Rupees per metric tonne kilometer for OVOD and RVED within a star network indicated that the OVOD scenario will prove more advantageous in comparison to RVED over an extended duration for 1PL, owing to its lower costs and reduced transit duration. Furthermore, when a logistics enterprise engages in long-haul road freight transportation, it has been observed that both the total transportation costs and transit times are considerably elevated. Consequently, the various stakeholders involved in the decision-making process are now equipped to make informed and judicious decisions, ultimately selecting the most optimal star infrastructure network that is specifically designed for the efficient transportation of long-haul freight.

CHAPTER 5

CONCLUSION, FUTURE SCOPE AND SOCIAL IMPACT

5.1 Conclusion

The development of structured road-rail freight transportation and cost models tailored to this complex landscape is critical for improving operational efficiency and reducing overall logistics costs. This conceptual article shows the feasibility as well as the impacts that the structured road - rail transportation system can create for India's logistics landscape. A structured approach is essential, in this study we utilized a thorough literature review, the survey of logistics companies and transporters to identify the key cost factors. The costs elements are incorporated based on a Bottom-up approach to cost estimation model, so that transport costs can be evaluated accurately in rupees per metric tonne per kilometre. The cost model framework is coupled to diverse networks like line, ring, and star networks to improve efficiency in different areas. It emphasize the multimodal logistics hubs, thereby MMLPs streamline the supply chain, leading to faster and more reliable delivery alleviating road congestion. Moreover, adopting technological innovations like TMS, AI, IoT applications integrated with ULIP will demonstrate formation of Intelligent freight transportation system for better fleet management and reduction transit time. In this research work the model was applied within the Delhi region upon three cases of line, ring, and star networks with a cost model framework proposed for each. Further the cost model of the star network was implemented by a logistic company for the stipulated long distance, where it was demonstrated that a systematic and structured and regulated transportation system adopting technological innovations like TMS, AI, and IoT applications integrated with ULIP will result in better fleet management , total transport costs decrease by 17 to 20% and The cost per metric tonne per kilometre ranges from 4.5 to 5.8 rupees. Therefore, these tests will assist in determining the scalability and generalisability of the model in various logistics contexts and improved fleet management and reduction transit time, total cost and further enhance the sustainability of freight transportation in India.

5.2 Limitations

a) Future research should quantify the combined effect of different fuels used in the transport sector.

b) Consequently, a wider variety of logistics company datasets is needed for testing of the proposed cost model framework implementation in India, considering different conditions of geographical locations, and industry sectors that rely on freight transportation.

5.3 Future Scope

a) To validate the practical relevance and efficacy of the developed cost models within different industries like agriculture, manufacturing & production, E- commerce companies, etc.

b) By constructing a same structured cost model for each state in India and combining them together on a grid, we can get better connectivity among railways, roads, inland waterways, and airport transportation services to reduce time and delivery costs to the maximum possible extent.

c) The project encompasses the comprehensive and intricate development of a specialized web application that effectively integrates technologies, such as TMS, ULIP, AI, IoT, and a meticulously designed cost model that ensures optimal resource allocation and improving efficiency, transparency, real-time monitoring and automated processes in the transportation sector and significantly enabling stakeholders in developing astute, data-centric judgments.

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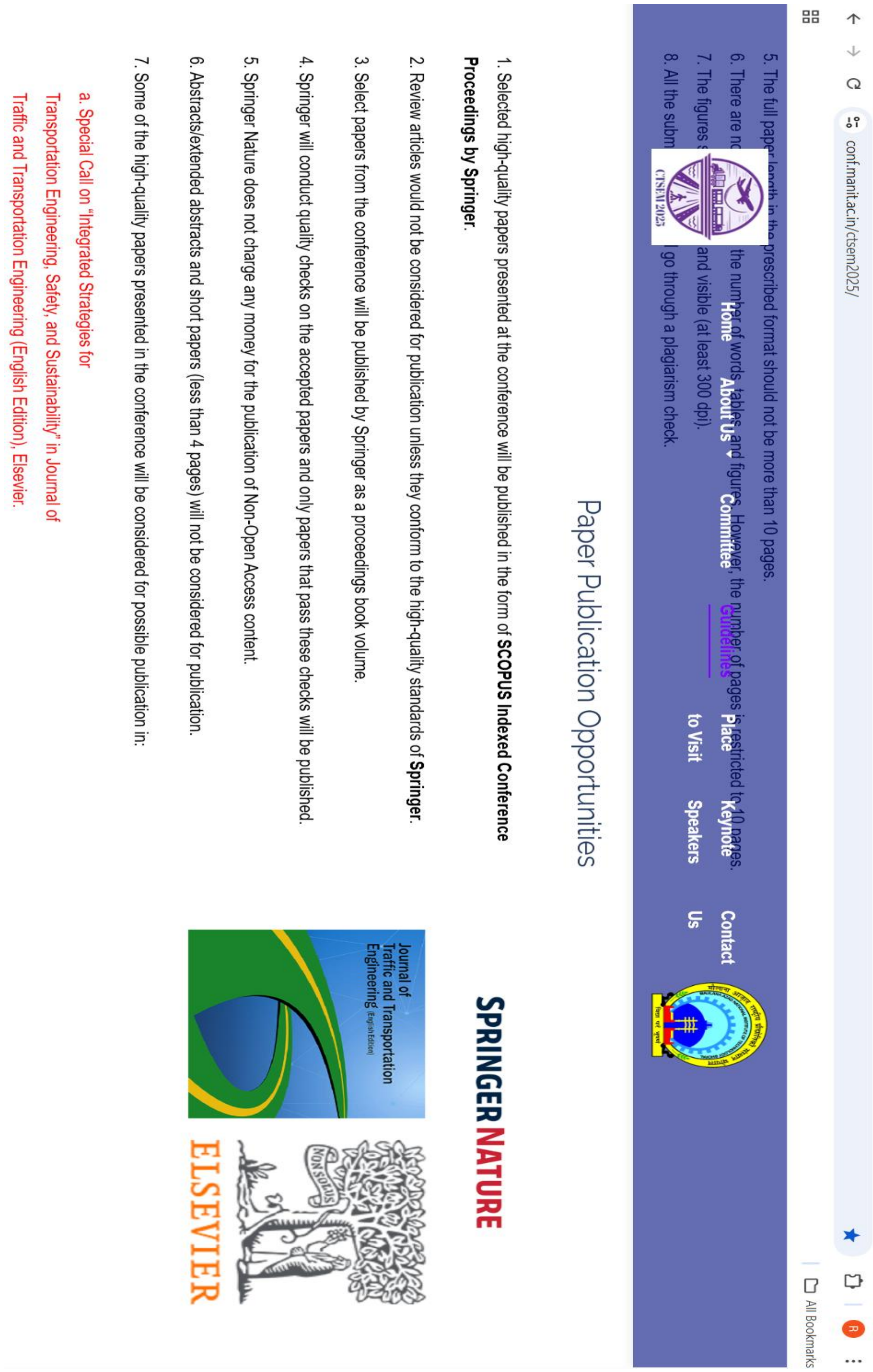

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EDUCATION			
Qualification	Educational Institute	CGPA/Percentage	Year of passing
M.Tech - Industrial Engineering and Management (IEM)	Delhi Technological University, Delhi	8.34	2025
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PROJECTS

B. Tech:

1. Self-transforming Carrier Vehicle

- Self-transforming carrier vehicle which is controlled by wireless controller along with voice controlling.
- Focuses on effective space utilization and inventory management using convertible container.
- Integrated an Automatic Beam Shifter Headlight and a Safe Distance Informing System using various industrial sensors for real-time safety and monitoring.
- Using Atmel ATmega328 and ATmega2560 Microcontroller Along with integration of Display methods such as 7SEG display.

2. Smart Traffic Density Controller

- Developed a density-based dynamic traffic signal system using IR sensors and ATmega328 microcontroller to optimize signal timings based on real-time traffic density and emergency conditions.
- Successfully reduced congestion and operational costs by automating signal changes with the help of RF Wireless Transmitter Receiver Module and minimizing unnecessary waiting times at junctions on road.

M. Tech:

1. **Data Analytics -** Company Financial Analysis using Python
   - Developed and compare logistic regression, decision tree classifier, gradient boosting classifier, random forest classifier Machine Learning algorithms to find insight of companies in Taiwan.
   - Apply machine learning frameworks (Pandas, XGBoost , NumPy , Scikit-learn) over 6819 listed companies and 95 features.
   - predictive models are used that Random Forest Classifier performs well with the accuracy of 99.67% as compared to other classifiers. And Results are displayed using data visualisation tools (Matplotlib, Seaborn, etc.).
2. **Industry 4.0 & Smart Manufacturing -** Smart Parking System
   - Designed and implemented an IoT Based Smart Parking system using ESP32 microcontroller and IoT sensors to provide real-time parking availability and optimize space management at university.
   - Enables users to check and book available parking spots, with automated message on WhatsApp or SMS.
   - Enhanced urban mobility by reducing congestion and improving parking efficiency through digitalization and cloud-based management services.

3. Advanced Operation Research

→ **Security And Safety Optimization at University Level**

- Evaluates and enhances campus security infrastructure through advanced technologies like Computer vision(CV) and RFID.
- The proposed Advanced security matrix and implementation plan have been put into operation at the university.

→ **Optimizing Solar Energy Utilization at DTU : Efficiency Enhancements and Growth Prospects**

- Assessing and analysing the solar energy potential across different areas of the campus using ML models
- Periodically ensuring Predictive maintenance, preventive and corrective maintenance activities
- Solar power potential mapping and proposed solar parking and charging stations, integrated with the combined system of Hybrid solar energy grid and organic waste-to-energy plant at the DTU campus

INTERNSHIPS

INDUSTRIAL SUMMER TRAINING 04/06/2019 – 15/07/2019	**NTPC - Faridabad Gas power station** • An analysis was conducted of the combined cycle technology and its role in optimising energy output and reducing emissions. • Conducted an in-depth study on the operational processes, efficiency, and environmental impact of Gas power plant.
INDUSTRIAL SUMMER TRAINING 18/06/2018 – 16/07/2018	**NORTHERN RAILWAYS, DIESEL LOCOMOTIVE SHED, TUGHLAKABAD, DELHI** • Perform Predictive Maintenance and Implementation of MRO practices and spare parts management in Diesel Locomotive • IoT and telematics enable data collection and real-time transmission for remote diagnostics. • Implemented predictive analytics solutions using RFID and Big Data to improve decision-making and optimize maintenance schedules.

SKILLS

Soft skills	Excellent problem-solving skills and the leadership abilities to work in a team environment , Ability to work in cross-functional teams , Effective communication and interpersonal skills , Leadership , Planning and Organizing skills, Quick Engaging with clients for understand their needs and deliver tailored solutions
Technical Skills	Certified Associate in Project Management (CAPM) , Microsoft Certified: Power BI Data Analyst Associate , Tableau Certified Data Analyst , Tableau Desktop Specialist , Oracle Database SQL Certified Associate, Excel Fundamentals - for Finance , Data Analytics using MS-Excel , Data Analysis with Python , Python Programming , Embedded C programming , C ++ Programming , Field Technician - Computing & Peripherals , PLC & SCADA and HMI & Drive, CNC programming, AutoCAD.
Other skills	IoT Developer Skills , Generative AI , Business analytics skills. , MS-Word and MS-PowerPoint (PPT) , proficient in mechanical and electronics systems , maintenance management skills.

EXTRA-CURRICULAR ACTIVITIES AND ACHIEVEMENTS

- Secured 2nd place in the Robo Hurdle event in 2019 at DSEU Okhla Phase II Campus (Erstwhile Delhi Institute of Tool Engineering, DITE)
- Secured 1st position in the Robo War event 2018 at Delhi Technical Campus

ACADEMIC ACHIEVEMENTS AND AWARDS

- DTU Teaching Assistantship (DTU-Teaching Assistant)

POSITIONS OF RESPONSIBILITY

- Class representative of M. Tech IEM at Delhi Technological University, Delhi
- Coordinator of Robo War & Robo Hurdle event in 2019 at DSEU Okhla Phase II Campus
- Coordinator of advertising committee in 2018 at DSEU Okhla Phase II Campus

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03. Year of Admission 2023

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Towards A Bottom-Up Cost Model Framework For Freight Transportation In India : Road and Rail Perspectives

Rajender

ABSTRACT

India's road and rail haulage sector is crucial to the country's economy, but it faces challenges due to fragmented operations, diverse regional practices, inconsistent infrastructure quality, and an unstructured nature. Hence, it results in inefficiencies and more expensive logistics, and therefore, the need for an accurate cost model specific to the Indian context is proposed. This conceptual article conducts an extensive review of the global and domestic literature to identify critical fixed costs, variable costs, and miscellaneous cost elements in freight transport and logistics. This conceptual article included the bottom-up approach to the cost estimation model to enable a more thorough evaluation of transport expenses. The cost model is linked to a variety of networks with in the structured vehicular and rail transit freight transportation system. So as to achieve real-time coordination and monitoring within India's intermodal freight transportation system, a multi-faceted technological approach is employed. This intelligent freight transportation system is utilised for effective control of transport workflow. The theoretical application of the cost model framework is applied for the Delhi region, where it is shown that the systematic transportation framework and the intelligent freight transportation system has the potential to lower the transit time and cost of transportation in India. Moreover, the comparative assessment will analyse both the total and per-unit costs of moving freight through a road-and-rail star network, benchmarking the results against traditional long-haul road routes that traverse multiple states. Based on the outcome from cost analysis, the company management accepts effectiveness and the least expenses and minimal time duration of transit in a star network as compared to traditional long-haul road transportation. The study concluded that the proposed cost model has the potential for implementation in real-world scenarios, contingent on the development of the web application. The implementation of the cost model framework would facilitate informed decision-making among stakeholders, thereby improving the performance of the transportation sector of India while reducing overall expenses and promoting sustainability.

Keywords : Cost model, Road freight transport , Rail freight transport, infrastructure network, Intelligent freight transportation system, Bottom-up approach.

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LIST OF ABBREVIATIONS

Abbreviation	Full Form
PPP	Public Private Partnership
GNSS	Global Navigation Satellite System
DFC	Dedicated Freight Corridor
MMLP	Multi Modal Logistics Parks
GIS	Geographic Information Systems
ANNs	Artificial Neural Networks
DWC	District Warehouse Center
AI/ML	Artificial Intelligence / Machine Learning
IoT	Internet of Things
TMS	Transport Management Systems
ULIP	Unified Logistics Interface Platform
3PL	Third-party Logistics
1PL	First Party Logistics
RFT	Railway Freight Terminals
FOIS	Freight Operations Information System
FTL	Full Truckload
LTL	Less than Truckload
PTL	Partial Truckload
SPSS	Statistical Package for the Social Sciences
ERP	Enterprise Resource Planning
WMS	Warehouse Management Systems
IFTS	Intelligent freight transportation system

3

CHAPTER 1

INTRODUCTION

Freight transport is the circulatory system of the modern world. It has always been important to commerce and our society. While freight transportation is influenced by the requirements emanating from the manufacturing sectors and consumer behavior as discussed by Zeng & Rossetti, et al., (2003) and also shown that the cost related to freight shipping has evolved into a significant economic yardstick of supply chain efficiency. Road networks are massively misused while little is invested in already existing infrastructure, leading to such externalities including transportation congestion, greater energy consumption, and a negative environmental impact. Road capacity is constrained mainly outside of metropolitan areas, and some road segments in growing economies are in deplorable condition as discussed by Bhattacharya et al., (2013c).

Road transportation is considered one of the most cost-effective and preferred means of conveyance for cargo due to its comprehensive accessibility to densely populated regions. Consequently, it serves as a vital function in the economic advancement and social cohesion of the nation. Unlike rail or air transport, trucks can reach remote locations and provide direct delivery, making it essential for various industries. India is aggressively pursuing a multi-faceted strategy to reduce road freight transportation costs, with major infrastructure development projects at its core.

Bharatmala Pariyojana, launched in 2017, This initiative prioritizes enhancing connectivity between key manufacturing hubs, ports, and consumption centers, while simultaneously addressing congestion bottlenecks through strategic bypasses and ring roads around major urban centers. The Dedicated Freight Corridor (DFC) project, The DFCs are being constructed on the Mumbai-Delhi (Western) and Delhi-Kolkata (Eastern) segment of the Golden Quadrilateral. IR’s Golden Quadrilateral, Although it comprises only around 16% of the total route length, it handles over half of the railway’s total traffic, although focused on rail infrastructure, indirectly benefits road transport by transitioning certain freight volumes from road-based to rail-based transportation, thereby reducing congestion and improving overall efficiency as discussed by Indian Railways, (2023).

The development of Multimodal Logistics Parks (MMLPs) across India promotes efficient consolidation and distribution of goods, offering value-added services and seamless intermodal connectivity, further optimizing logistics operations and reducing costs as given in Ministry of Commerce and Industry, (2022). Multi Modal Logistics Parks (MMLP) are designed to lower aggregate freight expenses and transit durations, reduce warehousing expenses, mitigate vehicular emissions and traffic congestion, and increase monitoring and traceability of shipments through strategic infrastructural, procedural and technology investments at disparate locations across the country aimed to reduce logistics costs.

Currently, the road networks carry a higher proportion of freight in comparison to the rail network, with the ratio of freight on roads at 74% as compared to the 26% on rail. About 0.5% of the total road network are the main road networks that carry a dominating 40% of the freight being moved by road. This results in congested road networks near about 115-150% of the total capacity utilisation. Moving one tonne of cargo by road cost Rs. 2.50 per kilometre, by rail was Rs. 1.36, by water just Re. 1.06. After feasibility studies to make them navigable, IWAI has identified 26 new national waterways as stated in ports industry report, (2024). Freight transportation contributes to about 50 per cent of the logistics costs in India, and currently roads are the costliest and the slowest mode. In addition, the Indian government aims to cut down the logistics and supply chain costs in India from 13-14% to 10% of the GDP in line with industry norms. It should be noted that in financial year 21 the logistics industry was divided by section where road has the highest % age share as transport mode at 73%, this is followed by rail at 18%, inland water at 4% and air which also registers 6%. On the other hand, 10% is organized and 90% unorganized road transportation, bringing about the overload of trucks, recurring road accidents, the rapid ageing of vehicles and degradation of the roads has been adopted in literature by Gupta & Dhar, (2022). Freight logistics across road and rail networks is marked by a mix of organized and unorganized players, plays a critical role in supporting economic growth, bridging industrial supply chains, and catering to the demands of a rapidly growing population, demand and supply.

The bottom-up approach in transportation emphasizes the importance of local interactions and detailed data collection to inform decision-making and policy development. Bottom-up models can adapt to real-time data and changing conditions, making them suitable for dynamic environments like urban travel behaviour analysis as discussed by Das & Winter, (2016) . A bottom-up methodology in transportation cost modeling entails determining the overall cost of a transportation service by systematically identifying, estimating, and aggregating the expenses associated with each constituent component or operational activity involved in delivering the service.

Subsequent to this, an in-depth examination of the cost model will be presented, focusing on star infrastructure networks, which reduce total costs by 17-20% and the cost per metric tonne per kilometre ranges from 4.5 to 5.8 rupees. The findings aim to inform stakeholders-including policymakers, industry leaders, and researchers-about the relative advantages and trade-offs of each mode, thereby supporting evidence-based strategies for optimizing India’s freight transportation along with sustainability.

1.1 Research Gap

i. Many existing models lack adequate consideration of ground realities such as informal transport sectors, overloading practices, empty running of trucks, small players in market, tax pyramiding, lack of Advance technologies integration, varying levels of infrastructure development across regions, and the impact of recent policy reforms like GST implementation of 5 and 12% .

ii. There is limited research on dynamic cost models that can accurately capture real-time fluctuations in variables like fuel prices, traffic congestion and geographical location.

iii. There isn't one single algorithm to determine road freight transportation costs in India. The existing cost models are only designed as per need of certain logistics company, and which is not applicable to India’s unstructured transportation system.

1.2 Research Objective

i. To develop a comprehensive framework for understanding and estimating road freight transportation costs, which can help streamline cost estimation and enhance transparency.

ii. To develop the cost model in detail for three types of infrastructure networks, that are, line, ring and star networks and it will account for the heterogeneity of the sector and incorporate strategies & cost model to deal with data limitations and uncertainties associated with the unorganized segment.

iii. To develop the web app Central theme of technological advancements known as Intelligent freight transportation system, formed by ULIP, AI and IoT and cost model.

CHAPTER 2

LITERATURE REVIEW

Road haulage is the vital of India's rapidly evolving economy, facilitating the transportation of items across significant distances and varied terrains. Understanding the cost structure of this crucial sector is essential for efficient logistics planning, pricing strategies, and infrastructure development. This literature review examines existing research on cost models for road freight transportation in India and other countries. Furthermore, this study aims to highlight limitations and unexplored dimensions within existing scholarly work and suggest potential avenues for future research in this domain.

In the literature by Izadi et al., (2020) presents various cost models. These models separate these costs into three categories: These can be classified as operating cost, value of time (VOT) and externality cost. The most fundamental techniques of approach to assessment of methods and measuring model of data collection structure in general are. The application of fuzzy approximations in modelling might help increase the accuracy of results. Prior studies indicate that the fuzzy techniques are not adequately incorporated in this area of study.

The research has been discussed by Zeng & Rossetti, (2003) aims to address the complexities involved in evaluating total logistics costs within international supply networks, especially concerning a prominent corporation in the United States aerospace sector and its corresponding supplier located in China. The authors propose a five-step evaluation framework that can be implemented using spreadsheet tools, allowing for flexibility in assessing various transportation alternatives and conducting sensitivity analyses. The results suggest that the logistics expenses make up a considerable part of the overall worldwide sourcing expenditures, which can influence the effectiveness of procurement strategies.

The study by Lingaitiene et al., (2008) focuses on building a mathematical to strategic model for determining cost-efficient and time-effective paths and transport facilities for multimodal freight transportation.

The study by Ďurišová et al., (2011) examines the use of cost models in transportation companies to enhance operational efficiency and cost reduction strategies. As a further point, the research relies on information obtained from a designated transportation company, which could restrict the applicability of the results to different settings or scenarios. Applied models have the drawback of being static and having varying degrees of influence on various parameters.

The investigated methodologies for calculating costs in the domain of road freight logistic, focusing on developing a more precise method for determining the upfront cost incurred in executing a particular transport activity. A software application was developed based on the proposed method, enabling transport companies to calculate first costs quickly and precisely. Findings indicate that the developed approach ensures cost accuracy within a 3.5% margin, significantly outperforming traditional estimation methods that deviate up to 12 as discussed by Kovács et al., (2017).

The study investigated by Kulovic & Se, et al., (2004) discussed the factors influencing road freight transport costs, focusing on the impact of truck fleet operational parameters. The research found that lost time, including waiting time and travel time, significantly influences transport costs.

The rising of handling costs at terminals, greater total transport distance, elevated pre- and post-haulage costs, greater distance-related marginal generalized costs of rail, lesser distance-related marginal generalized costs of truck, and decreased resting costs in case of truck drivers as discussed by Hanssen et al., (2012).

The development of comprehensive model to evaluate and compare the total costs incurred by intermodal infrastructures. Key findings reveal that intermodal networks benefit from economies of distance and scale, with cost reductions accelerating over longer distances and higher service frequencies as discussed by Janic et al., (2007).

The research study by Cheng et al., (2009) delve into the intricate world of intermodal freight transport costs, aiming to establish a clear and universally accepted method for their calculation. The authors highlight the significance of considering factors such as design, coordination, and random costs, often overlooked in traditional cost calculations.

A study by Conrad et al., (2018) examined the expenses and obstacles associated with transporting logs by truck. The research involved interviewing 18 log truck owners who operated in Georgia, USA. Findings revealed that the most significant challenges were Shortage of adequately trained driving personnel and the escalating cost of truck insurance. Also provide driver education and deploying technologies such as GPS tracking and in-vehicle cameras.

In the European metropolitan setting by Kordnejad et al., (2014) examined the intermodal distribution and the multimodal transport cost model and research aims to develop a conceptual framework for implementing a regional intermodal transportation system using rail for a distributor of essential consumer goods operating within an urban environment. Transport system and assess its cost and emissions. According to the findings, the overall expenditure associated with transporting goods by road encompasses both the costs incurred before and after transit to terminals. Similarly, the complete expenses linked to terminal operations are contingent upon the per-unit transfer costs specific to each terminal type.

The study by Levinson et al., (2005) conducted an analysis of the operating expenses associated with trucks. A survey targeting companies engaged in commercial truck transport was executed. And result in comparable ability for measuring total costs based on data. Furthermore, the models indicated the 1% rise in output total truckloads results in a 1.04% rise in total costs.

52 The study by Qiao et al., (2019) investigated a decision-making conundrum pertaining to dynamic pricing for less-than-truckload shipments within the framework of the Physical Internet (PI). The research outcomes revealed that the proposed model possesses the potential to enhance the bidding price of carriers, thus augmenting anticipated profits, and three pivotal factors were investigated: the number of calls, the capability of the carrier, and the cost of the service.

50 The research by Zofío, Condeço-Melhorado, et al., (2014) investigated the overarching costs associated with freight transportation by employing a geographical analysis of economic and infrastructural fundamentals. Generalized transport Costs GT C within a value index of transit can be a deflator that separates cost and volume index for economic market transport costs within the necessary transport network, distance and time. The changes in road freight movement in Spain has been analyzed in detail from 1980 to 2007 at disaggregate geographical level. The mean GTCs, adjusted for trade movement, has experienced a decline of 16.3%, with infrastructural developments facilitating this reduction.

The study proposed by Z. Zhang & Eng, (1993) to optimization framework for scheduling freight truck drivers predicated on an operational cost assessment model adapted to the operational structure of Less-than-Truckload logistics services. They presented a special time driven ABC model was oriented majorly towards improving efficiency in truck freight businesses. In addition, ANN model was developed to establish relations between fuel usage and driving behaviour. The limitations in prior models for estimating transport costs by proposing a comprehensive framework that incorporates factors such as transport supply and demand, infrastructure quality, route-specific characteristics, and firm-level strategies.

Utilizing data from 583 interviews and 6,390 observations across 305 routes within Europe, identifies both linear and quadratic relationships between distance and transport costs, providing nuanced insights into modal preferences and cost behaviours over varying distances. The model's predictive power (adjusted R^2 = 0.814) underscores its robustness, that has been adopted in literature by Camisón-Haba & Clemente-Almendros, (2020).

This systematic literature review by (Barakchi et al., 2017) investigates the various cost estimation methods used in transport infrastructure projects. The review identified around 12 distinct cost estimation methods, with the parametric, ANNs are mostly used in many literatures. The authors discuss how these methods differ in terms of accuracy, usability/application, and ease of understanding key attributes that influence their suitability for specific transport infrastructure projects.

The study by Fumasoli et al., (2016) has discussed that four alternative scenarios are developed for integration of urban rail into a freight system and then evaluated based on a Business as Usual scenario. Emissions, handling time and fuel consumption metrics are analyzed, with results showing significant benefits in decreasing emissions by 97.8% down to BAU by 2026.

The study by Callefi et al., (2022) responding to an important knowledge gap in the literature, to identify and evaluate technology enabled capabilities that constitute road freight transportation systems, a multi method study is based on this. The authors employ a comprehensive multi-methodological framework that integrates a systematic review of existing literature alongside the analysis of secondary data sources. and expert validation to note their end. Based on the SLR, we identify 32 distinct technology enabled capabilities, distributed into six groups, and discussing the role that each of these technologies, namely those of I4.0 like blockchain and IoT, plays in optimizing freight transportation operations. Results of the findings show that 28 out of the 43 capabilities on the scale had commercial applicability and stakeholder information value to the industry including shippers and carriers with respect to how ready these capabilities might be to be implemented.

The research by Kumar et al., (2019) was primarily designed to deal with complexity of sustainable freight systems through development of analytical models to support making choices in logistics. As part of the objectives, a bi-objective optimization model is to be developed to minimize transportation costs and carbon emissions and explore intermodal transportation system within the Turkish transportation industry.

The study methodologically employs the ε-constraint method and ODS to obtain Pareto optimal solutions that trade off cost and environmental impact. Experiments show how the proposed models produce feasible solutions that are 3 to 7% faster than the existing algorithms, this helps logistics companies to reduce their operating expenses as discussed by Carboni & Dalla Chiara, (2018).

The rail freight is recognized for its lower carbon footprint and reduced external costs has been extensively investigated by Dhulipala & Patil, (2024). The main findings are the functional relationships among the various ways of transport. The research by

Ravibabu et al, (2013) examines the variables that affect the choice of inland transport modalities for containerized export freight in India.

Sachan et al., (2024) has presents a comprehensive study aimed at addressing the inefficiencies in logistics transportation planning, particularly within the context of the One District-One Product initiative in Uttar Pradesh, India. This investigation seeks primarily to establish a novel cost function that incorporates various cost components, including unit transportation costs, labour costs, operational costs of spokes, and establishment costs of hubs, thereby providing a more accurate representation of logistics expenses. To achieve this, the authors employed a meta-heuristic approach, utilizing eight well-established algorithms to solve the logistics optimization problem.

The research by Sharma et al., (2024) aims to analyse the Indian railway freight business, employing a multifaceted methodology that includes literature reviews and data from the Indian Railways Year Book . Key findings indicate a decline in freight performance due to competition and inefficiencies, with recommendations for future studies on sustainability and operational improvements . Limitations include reliance on secondary data, suggesting a need for primary data collection in future investigations.

The study by Bhattacharya et al., (2014) has delved into the complexities of intermodal freight transport systems, with a particular focus on enhancing the performance of supply chain logistics. The methodology employed involves a two-step process. The MIP optimization model successfully identifies cost-effective and time-efficient intermodal transport strategies, assess the trade-off between operational expenses and transit delays.

Singh & Gupta, (2020) has explores if and how the urban rail infrastructure of the Delhi Metro and Ring Rail systems could be used to distribute freight, focusing with the postal and courier services. By examining whether these existing, underutilized passenger rail systems during off peak hours can be repurposed to carry urban freight as a way to relieve congestion and reduce pollution while improving efficiency by passively taking advantage of the declining passenger load in benefitting from the existing infrastructure and train fleets and operating cycles of the current passenger trains without capital expense.

Freight transport research increasingly relies on statistical tools to analyse, forecast, and optimize operations. SPSS (Statistical Package for the Social Sciences) is a widely used software in this field, supporting data analysis, prediction, and decision-making processes for freight companies as discussed by Younes & Naji, (2022).

The study discussed by Ambast et al., (2024) examines GST's impact on profitability in logistics by comparing pre- and post-GST data from 2013 to 2022 for six companies using Shapiro Wilk tests, correlation analysis, and paired t-tests in R Studio. Results reveal that GST significantly improved profitability in logistics while impacts on education and hospitality were mixed or statistically insignificant. Limitations include small sample size and short duration, suggesting future broader, longitudinal research.

2.1 Bibliometric analysis of freight transport.

Bibliometric analysis aiming to uncover patterns, trends, and the structure of research within a specific domain. It is prominent approach for reviewing and analysing scientific publications, as stated by Merigó & Yang, (2017) . In this investigation, we used the bibliometrix R-package produced by Aria & Cuccurullo, (2017). This study utilizes SCOPUS and Web of Science (WOS) database was employed as the primary source for literature retrieval to maintain a high standard of scholarly quality in the reviewed studies. In Fig. 2.1, word cloud of most frequent keywords identified by bibliometric analysis is shown. The top five words with frequent occurrence are sustainability, logistics, transportation, supply chain and India.

Fig. 2.1: Word map of most frequent keywords (source: R- Shiny)

Fig. 2.2 shows the frequency of words of most frequent word in100 selected research articles, and it can be concluded that industry 4.0 in freight transportation is having most appearance in research articles since 2015.

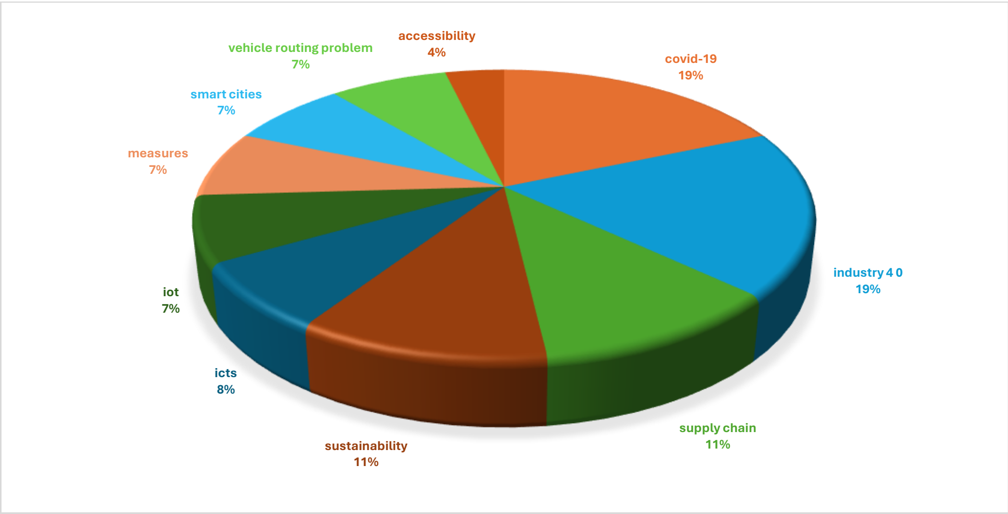

Fig. 2.2: Pie chart of Most Frequent Words (source: R- Shiny)

The Fig. 2.3 shows the co-occurrence network, generated using VOS viewer, of main keywords namely, road transport, rail transport, logistics, performance measures, etc.

Fig.2.3: Keyword co-occurrence network structure (source: VOSviewer)

The fig. 2.4 show the interconnection of 40 research articles in similar work of corresponding authors in the span of 10 years. The maximum interconnection of similar work is obtained by Mostert et al., (2017a) and Janic et al., (2007) . Therefore organize, analyse, and connect ideas from existing literatures to cost model development

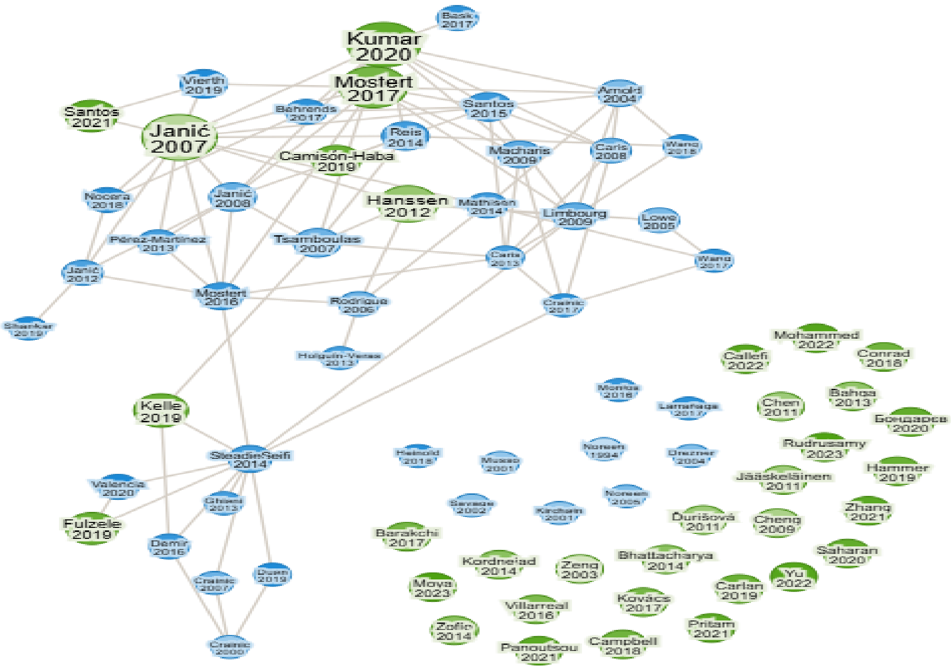

Fig. 2.4: Similar work interconnection graph (source: R- Shiny)

Fig. 2.5 shows the sources' production over time period of 10 years of words over time, and it can be stated that Transportation research Procedia published articles.

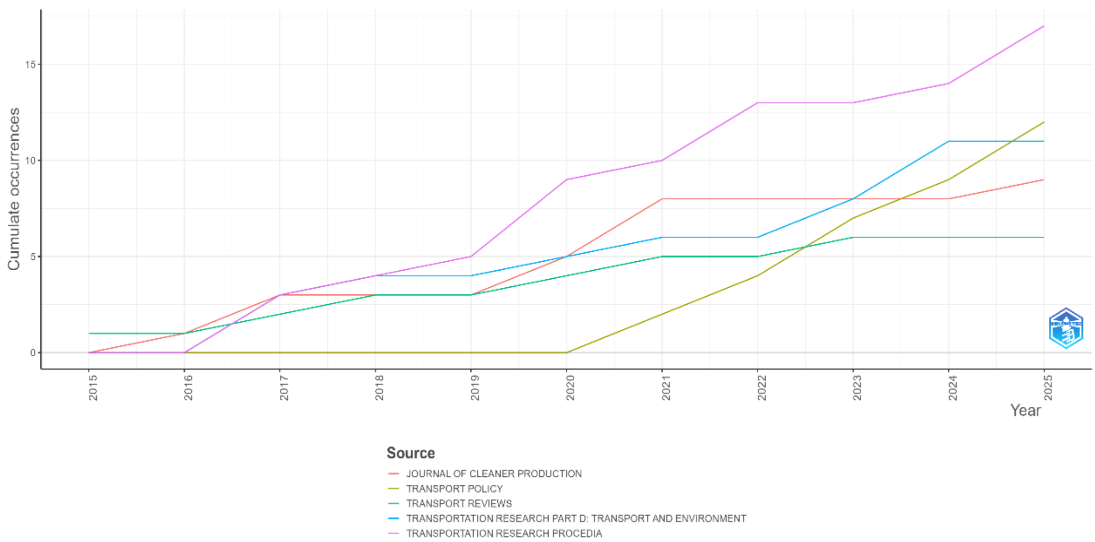

Fig 2.5: Sources' production over time (source: R- Shiny)

In the three-field plots shown in Fig. 2.6, interconnection between 15 sources, 12 keywords and 15 abstracts is shown. The main relationships are shown below in figure with words being sustainability, transportation, decarbonization, freight, etc.

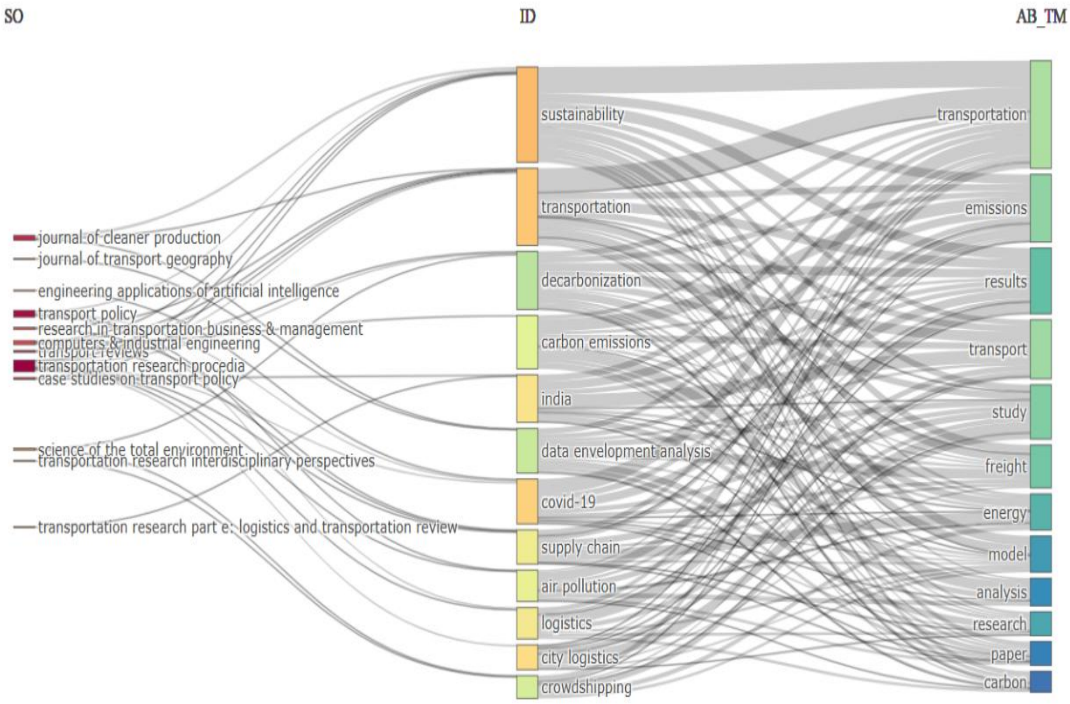

Fig. 2.6: Three-field plot of keywords, sources and abstracts. (source: R- Shiny)

2.2 Cost Factor Identification and Selection

This literature review has examined existing research on road freight transportation cost models revealing a diverse range of approaches and methodologies. Studies have explored various factors influencing costs. Table 2.1 summarises the essential elements of these research, including their major cost classification and a freight cost calculation approach adopted in this research. The considered publications are also grouped into Factors impacting road and rail Freight Transportation Cost in Table 2.2. This methodology utilizes a simplified analytical framework that identifies the key cost components of the transport chain, both internal and external. It turns out that the economic benefits of rail-road combined transport to rail - road alone depend very strongly on the level of efficiency of pre and post transport phases, and from that point of view the economic benefits of rail-road are not so sufficient to take advantage of the combined transport option. In this study to further refine the cost estimation, the model should incorporate the following factors in Road-Rail freight transportation, and these final factors are shortlisted based on drawing upon existing scholarly research and the survey of logistics companies and freight forwarder to identify the key cost factors for the application of proposed method. A thorough description of these cost factors is given in Table 2.3. But of course, the foremost financial planning is must to have the business running and financial Plan is mandatory where a comprehensive outline of your initial investment, how you'd be funding much of the endeavour with various sources, projections on the revenue that is going to help you set your expected financial outlook, and all the calculations that are going to help you determine your profit margins from this venture. In general, the profit margins observed in the transport industry can be highly variable and appropriately on the order of 10 percent to as high as 30 percent, which is strongly impacted by the efficiency of such management practises and projected demand, competition, seasonality, and varied terrain across India affecting business activities.

Table 2.1. An overview of the research articles on freight cost estimation

References	Cost Classification		Methodology								
	Operational	Externalities	ABC	Mathematical	Statistical	Survey	Data Mining	GIS	Meta-Analysis	Fuzzy	others
Zeng ,Rossetti, (2003)	⊙	⊙			⊙						
Ravibabu et al., (2013)	⊙										⊙
Bhattacharya et al., (2013)	⊙			⊙							
Sachan et al., (2024)	⊙			⊙							
Ďurišová et al., (2011)	⊙										⊙
Kovács et al., (2017)	⊙			⊙							
Kulović et al., (2004)	⊙				⊙						
Hanssen et al. ,(2012)	⊙			⊙							
Janic et al., (2006)	⊙	⊙			⊙						
Yao-Rong et al., (2009)	⊙			⊙							
Bierwirth et al., (2012)	⊙			⊙							
Carlan et al., (2019)	⊙	⊙		⊙		⊙					
Conrad et al.,(2018)	⊙										⊙
Kelle et al., (2018)	⊙	⊙		⊙							
Kordnejad et al., (2014)	⊙	⊙			⊙						
Levinson et al., (2005)	⊙		⊙			⊙					
Lindsey et al. (2013)	⊙						⊙	⊙			
Mostert et al., (2017)	⊙	⊙							⊙		
Qiao et al., (2016)	⊙			⊙							
Radhakrishnan & Anukokila, (2014)	⊙									⊙	
Zofio et al.(2014)	⊙						⊙	⊙			
Zhang et al., (2018)	⊙		⊙	⊙							

Table 2.2. Key elements contributing to the financial outlay in freight logistic

Factors that influence cost				
Operational costs		Value of Time	External Costs	Reference
Fixed costs	variable costs			
i. Order processing ii. Administration Costs iii. Customs clearance Fees iv. Brokerage fees v. Allocation fees vi. Packaging/supplies Costs	i. Consolidation fees ii. Transfer fees iii. Pickup and delivery charges iv. Pipeline holding costs v. Terminal handling charges vi. Material handling costs vii. In/out handling charges viii. Disposal charges	i. Transit times ii. Manufacturing time	i. Damage/loss/delay cost ii. Insurance	Zeng & Rossetti et al., (2003)
i. Terminal handling costs	i. Haulage costs ii. Repositioning charges	i. Transit time ii. Detention at terminals	i. Loss and damage cost	Ravibabu et al., (2013)
i. Crew operating costs ii. Maintenance iii. Fuel costs.	i. Vehicle transfer/transshipment costs ii. Loading and unloading costs iii. Drayage costs	i. Transit times		Bhattacharya et al., (2014)
i. Vehicle excise duty ii. Vehicle insurance iii. Drivers' guaranteed wages iv. Overheads v. Capital investment vi. Insurance vii. Registration fees	i. Fuel cost ii. Fuel taxes iii. Oil cost iv. Tires v. Maintenance and repair vi. Crew wages vii. Paid parking viii. Toll taxes	i. Travel time ii. Reliability iii. Frequency iv. Flexibility	i. Environmental cost ii. Accidents iii. Congestion	Izadi et al., (2020)
i. Technological Costs ii. Driver Payments	i. Fuel Costs ii. Maintenance and Repairs: iii. Road Taxes iv. Loading and Storage Costs	i. Total Time Expenses ii. Relative Expenses in Terms of Time(delay time)	i. Insurance Expenses ii. Non-provisioned Downtime	Lingaitiene et al., (2008)
i. Vehicle Depreciation ii. Liability Insurance iii. Accident insurance iv. Realtrans Charges v. Wages of drivers vi. Vehicle Insurance	i. Fuel consumption ii. Tyre abrasion iii. Oils and lubricants iv. Service and maintenance		i. Technical Requirements for Vehicles	Ďurišová et al., (2011)

Table 2.2 Continued

Factors that influence cost				
Operational costs		Value of Time	External Costs	Reference
Fixed costs	variable costs			
i. Truck payments ii. Licenses, tags	i. Driver wages, benefits, and overhead ii. Fuel cost iii. Tires cost iv. Maintenance and repair			Conrad et al., (2018)
i. Infrastructure investments ii. Terminal and yard facilities	i. Fuel consumption ii. Labor costs iii. Vehicle operating costs	i. Travel time ii. Reliability	i. Traffic congestion ii. Accidents	Kelle et al., (2019)
i. Infrastructure Costs ii. Terminal Handling Costs	i. Operational Costs ii. Loading and Empty Run cost	i. Transportation Time ii. Service Times at Nodes	i. Environmental Impact ii. Congestion Costs iii. Reliability and Punctuality	Kordnejad et al., (2014)
i. License Fees ii. Insurance iii. Interest Charges of vehicles	i. Fuel Consumption ii. Engine Oil Consumption iii. Tire Costs iv. Maintenance Costs	i. Driving Conditions ii. Length of Hauls	i. Policy Restrictions ii. Environmental Impact	Levinson et al., (2005)
i. vehicle Type: The type of truck used (e.g., van, flatbed, refrigerated)	i. Distance ii. Number of Stops iii. Cargo Type iv. Lead Time	i. Seasonality ii. Market Conditions		Lindsey et al., (2013)
i. Infrastructure Investments ii. Terminal Capacity	i. fuel costs ii. maintenance iii. labour		i. Human Health External Costs: ii. Air Pollution Costs	Mostert et al., (2017)

Table 2.2 Continued

Factors that influence cost				
Operational costs		Value of Time	External Costs	Reference
Fixed costs	variable costs			
i. Amortization cost of vehicles ii. Insurance costs	i. Cost of transport way with/without useful load ii. Fee of motorway usage iii. Cost of waiting time during the transport way iv. Driver's labour costs v. Maintenance cost of vehicles			Kovács et al., (2017)
i. Drivers ii. Depreciation and Interest iii. Overheads	i. Fuel ii. Lubrication Oil iii. Tires iv. Spares			Kulovic & Se, (2004)
i. Terminal Handling Costs	i. Pre- and Post-Haulage Costs ii. Long-Haul Transport Costs	i. Transport Time ii. Time Cost of Freight iii. Resting Costs for Truck Drivers		Hanssen et al., (2012)
	i. Truck operation cost ii. Main transport mode cost (intermodal network) iii. Handling cost	i. Time cost of goods in transit	i. Time cost of goods in transit ii. Congestion iii. Traffic accidents	Janic et al., (2007)
i. Design cost ii. Exclusive cost	i. Transshipment cost ii. Loading and unloading cost	i. Time value cost	i. Random cost from unpredictable external factors	Cheng et al., (2009)
	i. Full-train-load cost ii. Less-than-train-load cost iii. Terminal handling charges	i. Transit time		Bierwirth et al., (2012)
	i. Time and Distance Costs ii. Tolls and Fees iii. Truck and Chassis Usage Costs		i. Emissions cost	Carlan et al., (2019)

Table 2.2 Continued

Factors that influence cost				
Operational costs		Value of Time	External Costs	Reference
Fixed costs	variable costs			
i. Labour Costs ii. Financial Costs iii. Insurance Costs iv. Taxes v. Administrative overheads Operating expenses vi. Commercial costs	i. Fuel Costs ii. Maintenance Costs	i. Value of Time Indices(taking into account various characteristics that affect time and distance)	i. Environmental Costs ii. Congestion Costs	Zofío, Condeço-Melhorado, et al., (2014)
i. Vehicle costs ii. Insurance fees iii. Licenses and permits	i. Fuel costs ii. Repair and maintenance fees iii. Tolls Taxes	i. Time spent on administrative activities ii. Time spent on rest breaks due to Hours-of-Service	i. Environmental costs ii. Accidents iii. Traffic congestion iv. Noise pollution	Z. Zhang & Eng, (1993)
	i. Distance ii. Volume of Freight iii. The degree of competition among logistics operators	i. Transit Time	i. Energy Consumption ii. Logistics Efficiency	Camisón-Haba & Clemente-Almendros, (2020)
i. Infrastructure Costs ii. Vehicle Ownership Costs	i. parking pricing ii. Energy Costs for Electric Vehicles (EVs)	i. congestion pricing ii. Schedule Delay	i. Environmental Costs ii. Accident Costs	Saharan et al., (2020)
i. depreciation of Vehicles ii. Insurance Costs iii. Licensing and Registration Fees	i. Fuel Consumption ii. Toll Fees iii. Repairs & Maintenance Costs	i. Travel Time ii. Waiting Time	i. Environmental Impact Costs ii. Congestion Costs iii. Accident Costs	Fulzele et al., (2019)
i. Establishment Costs of Hubs ii. Rental Costs of Distribution/Collection Centers (DCCs)	i. Transportation Costs ii. Loading/Unloading Costs	i. Transportation Time	i. Environmental Costs ii. Market Competition Costs	Sachan et al., (2024)

Table 2.3: Description of cost factors selected for the cost model

Cost Factor	Description	References
Distance travelled	This is a primary cost generally increasing with distance travelled.	(Camisón-Haba & Clemente-Almendros, 2020), (Ahmad et al., 2024)
Administrative and online services	Refers to expenses incurred for managing operations, documentation, legal compliance, SEO, Social Media Marketing and Website Creation	(Zeng & Rossetti, 2003) , (Zofío, Condeço-Melhorado, et al., 2014)
16 Commercial Vehicle cost	Different vehicle types have varying operating cost and depreciation cost over the vehicle's useful life [own vehicle] Selective Rental vehicle cost	(Saharan et al., 2020) , (Bhattacharya et al., 2014) , (Izadi et al., 2020) , (Lindsey et al., 2013)
Useful Load	The weight and volume of the cargo influence fuel consumption and overall costs	(Kovács, 2017), (Cheng et al., 2009), (Santén, 2017)
Mileage	Number of miles a vehicle can travel per unit of fuel consumed, (km/L). changes significantly with topographical conditions and useful load.	(Taefi et al., 2017), (Gerondeau, 1996)
Fuel Prices	Fluctuations in fuel prices of different types of fuel, which directly impact transportation costs, influence the variable cost per km. considering fuel efficiency.	(Z. Zhang & Eng, 1993), (Mostert et al., 2017b), (Conrad, 2018)
Fuel consumption	Fuel consumption is the amount of fuel used by a vehicle to travel a distance.	(Fulzele et al., 2019),(Levinson et al., 2005), Ďurišová, 2011)
Toll Charges , Taxes and national permits	Toll charges in India are fees collected for using specific roads or highways, taxes include vehicle tax imposed by the government, and national permits allow commercial vehicles to operate across multiple states.	(Fulzele et al., 2019), (Zofío, Condeço-Melhorado, et al., 2014)
Driver and support staff cost	Maintenance crew cost (if in-house) during travelling plus Driver Base salary plus daily allowances for food and lodging, and benefits of insurance . [own driver] external driver (outsourcing) cost.	(Bhattacharya et al., 2014), (Conrad, 2018), Kulovic & Se, 2004.)
Maintenance and spare parts cost	Maintenance and spare parts costs in road freight transportation encompass expenses for upkeep, repairs, and replacement parts to keep vehicles and equipment operational.	(Fulzele et al., 2019), (Z. Zhang & Eng, 1993), (Conrad, 2018)
Insurance and EMI cost	In India, insurance refers to a premium paid for financial protection of assets like vehicles, while EMI a fixed monthly payment for repaying loans.	(Fulzele et al., 2019), (Zofío, Condeço-Melhorado, et al., 2014)
Loading-unloading Labour Costs /handling charges	Costs associated with loading and unloading cargo at the origin and destination, it is varied according to good and material types to be loaded, Packed, and palletized.	(Hanssen et al., 2012), Zofío, Condeço-Melhorado, et al., 2014), (Sachan, 2024)
34 Licensing and Registration Fees(RTO charges), fitness certificate charges	RTO charges in India include registration, road tax, and transfer fees for vehicles, while fitness certificate charges are fees for certifying a commercial vehicle's roadworthiness.	(Fulzele et al., 2019), (Saharan et al., 2020), (Levinson et al., 2005)

Table 2.3 (continued)

Factor	Description	References
Overhead costs / Infrastructure Costs	Core transportation activities in road and rail freight operations have expenses that support their operations without directly participating in freight movement. The infrastructure costs in road and rail freight transport refer to the capital and operational expenditures for building, maintaining.	Kulovic & Se, (2004), Izadi et al., (2020), Saharan et al., (2020), Mostert et al., (2017)
Transporter margin %	Percentage of Revenue remaining after deducting all operating costs.	Danylenko & Borovik, (2022) , Nuño-Ledesma & Villoria, (2019)
Wagon type	It Refers to the specific category of rail freight wagons designed to transport different types of goods	Moya et al., (2023), Wiesław et al., (2016)
Cargo Type / commodity category	The classification of goods based on their nature, size, weight, or handling requirements for transportation and logistics. For exam Bulk Cargo, Containerized Cargo, Specialized Cargo, Liquid and Gas Cargo.	Zhao et al., (2024), Gera et al., (2024)
Parking cost	Parking cost refers to the fee charged for temporarily parking a vehicle in designated spaces, such as public lots, garages, or private areas.	Saharan et al., (2020) , Alho et al., (2022) , Campbell et al.,(2018)
Container Costs	Cost incurred for selecting special container as per types of goods loaded	Ding & Wang et al., (2022)
Environmental Costs	Environmental costs refer to the air pollution, greenhouse gas emissions, and noise pollution caused by transportation activities	Sachan et al., (2024) , Saharan et al., (2020) , Zofío, Condeço-Melhorado, et al., (2014), Izadi et al., (2020)
Cargo Insurance	Coverage for goods-in-transit and any claims arising from accidents or damage.	Cueva Clemente et al., (2022), Kotenko et al., (2022) , Kang et al., (2020)
GST	GST on rail and road freight transportation in India is generally levied at 5%, with some exceptions and variations depending on the specific goods and services involved	Ambast et al., (2024) , Fulzele et al., (2019)
Transit times	Cost varies according to date and time of delivery	Sachan et al., (2024) , Camisón-Haba & Clemente-Almendros et al., (2020)
Market Dynamics	Consider supply and demand factors and competition in the region, which can influence pricing and availability of trucks.	Li et al., (2018) , Baindur & Viegas, (2011)
Freight Tariff	It is the rate charged by a railway operator for transporting goods, determined by factors such as commodity type, distance, wagon type, and applicable surcharges.	Vydashenko & Askarova, (2024), Smith et al., (2007), (Sharma et al., 2024)
Warehousing charges for storing	It refer to the fees levied for holding goods in a storage facility, based on factors like duration, space occupied, and special handling requirements.	Tikito et al., (2010), (Pan & Yang et al.,(2021)

CHAPTER 3

FORMULATION OF THE PROBLEM AND SOLUTION APPROACH

3.1 Method selection

For determining the effective cost in terms of Rupees per metric ton per kilometer within the expansive and complex landscape of the Indian road- rail freight transportation sector are of paramount importance. In order to achieve this, a Bottom-up approach to cost estimation model tailored for Road and Rail freight operations in India would employ a meticulously structured approach that seamlessly incorporates a multitude of key variables that significantly influence transportation costs. Subsequently, the mathematical model would delineate and establish intricate relationships between these identified parameters, thereby elucidating their interdependencies and collective impact on overall cost calculations. The model for road and rail freight in India would utilize a structured approach that includes different infrastructure network and examines model based on fixed costs , variable costs, Miscellaneous Costs. Next, the model would establish mathematical relationships between these parameters. It would then integrate these individual cost components into a comprehensive formula. By methodically inputting specific shipment details into this sophisticated model, one could derive a highly reliable estimate of the overall costs associated with road - rail freight transport.

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3.2 The Conceptual Framework of Cost Model

In the Indian context, a limited number of logistics enterprises possess proprietary commercial vehicles designated for transporting goods from manufacturers to retail outlets or distribution centres. Conversely, most logistics firms engage with freight forwarding vendors or third-party logistics (3PL) service providers, who procure freight quotations predicated upon the shipment specifics provided. The Fig. 3.1 shows the conceptual framework depicting the Structured approach to Road and Rail Freight Transportation. It outlines key steps for converting from an unstructured to a more structured road freight transportation system in India. It begins by characterising the current unstructured scenario and proceeds towards the creation of a structured system through data collection, policy formulation, infrastructure development, technological integration of Fuel Efficiency, AI and IoT, and ULIP for both inhouse and outsourced transportation services and finally structured and regulated system becomes the catalyst for cost reduction and system modernization.

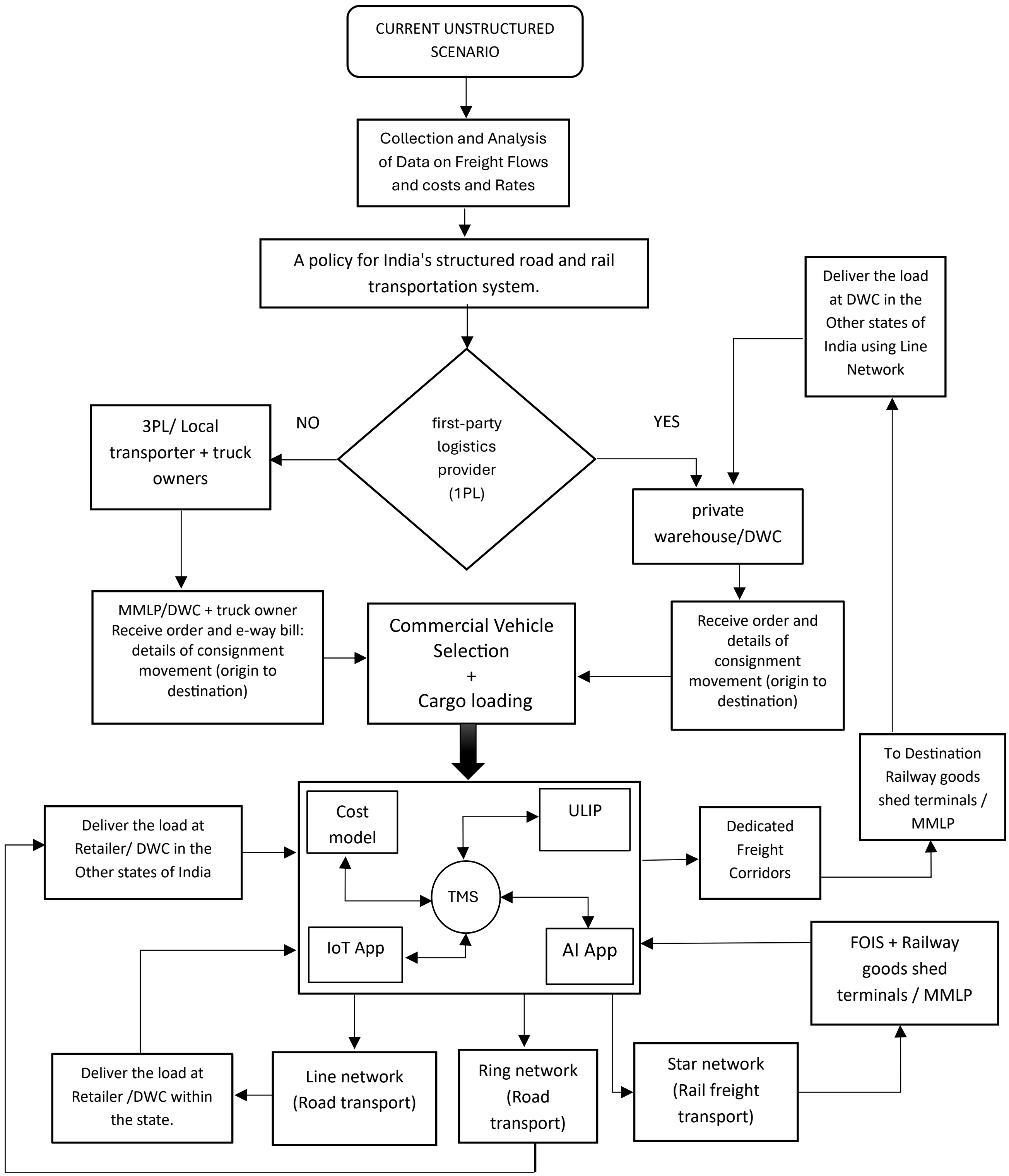

Fig. 3.1: Conceptual framework of the structured Road-Rail Freight Transportation

3.2.1 Current scenario

The road freight sector in India exhibits a significant level of fragmentation. Approximately 75% of the market is accounted for by small owner-operators with up to five trucks. In contrast, large fleet operators with more than 20 trucks account for a mere 15% of the market. Small players encounter challenges in optimising driving patterns and lack the resources to invest in larger vehicles, digital tools, software, and expertise. This market structure gives rise to reduced asset utilisation. This has been shown to result in inefficiencies and higher costs. Furthermore, the 3PL company failed to verify and authenticate the owner and driver of the local trucks, resulting in theft and damage to transit inventory.

3.2.2 Collect and analyse data on freight flows and movements

To adequately analyse India's freight transportation network, extensive surveys and stakeholder interviews is conducted. This procedure depicted in figure 3.2, entail collecting data Prior to the formulation of an output for the cost model, from a variety of sources, including toll plazas, RTO office, freight brokers, logistics companies, and NHAI, NITI Aayog, NICDC Logistics Data Services (NLDS), MoRTH of Government of India, central warehousing corporation of India, FOIS Indian railway, local transporters and logistics companies.

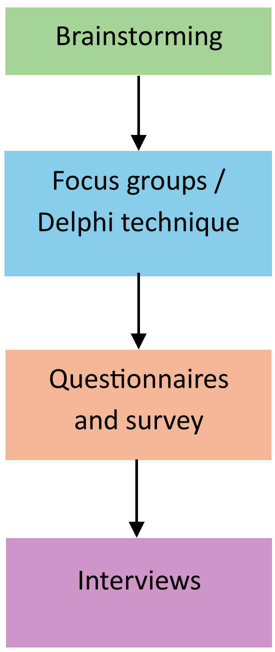

Fig. 3.2 : Procedure of data collection

3.2.3 Draft a policy for India's structured road and rail transportation system.

To ensure a strong and inclusive approach to organizing and regulating India's road freight transport system, a national-level strategy should be devised in collaboration with stakeholders. This policy include specific instructions for constructing line , star, and ring infrastructure networks to optimize freight flow and alleviate urban congestion, extensive time and costs through empty running. And it should support public-private partnerships for infrastructure development and prioritize driver authentication , training and welfare programs to solve problem like theft, skill issues and lack of motivation of driver and improve road safety and prevent road accident. Significant infrastructure development is necessary to successfully operate a structured road freight transportation system. This involves building and renovating essential Rail corridors along major roads, creating well-equipped multimodal logistics parks, for seamless transfers between modes of transportation, and implementing these road networks to promote connectivity in both rural and urban areas.

Furthermore, standardized loading/unloading zones and parking facilities. There are 28 states and 8 union territories in India, interconnected with a huge road network infrastructure. In order to establish a structured and systematic transportation system, a network of girds is formed. These girds are the result of connecting line, ring and star network structures.

i. A line infrastructure network establishes a linear, two-way flow for goods or materials as shown in figure 3.3. It connects a District Warehouse Center (DWC) to both retailers, who receive a distributed goods, and suppliers, who provide materials for procurement. The simplicity of this network allows for easy integration with other intermodal transportation networks

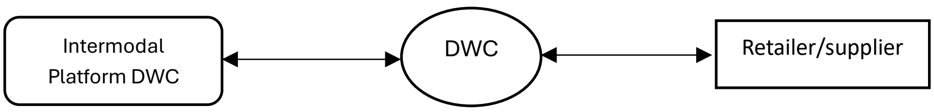

Fig. 3.3: Line infrastructure network

ii. A ring infrastructure network as shown from Figure 3.4, is constituted by DWCs situated in jurisdictions that are positioned along the periphery of the state. These DWCs are interlinked in a circular configuration to establish a closed-loop system. Consequently, it is Inter-district movement of commodities in the state and adjacent states can be executed with a high degree of efficiency.

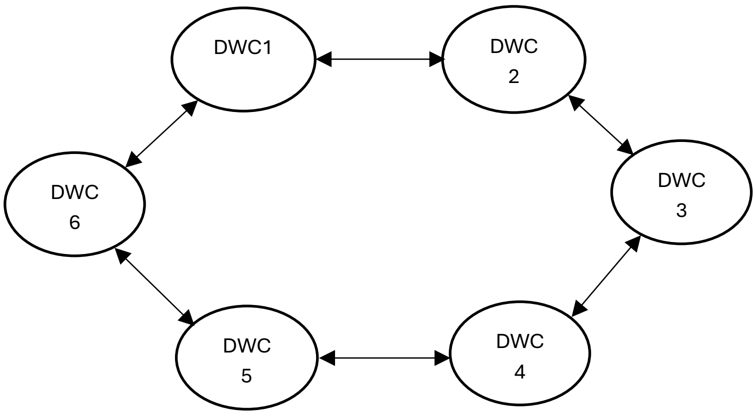

Fig. 3.4 : Ring infrastructure network

iii. A star infrastructure network as shown from Figure 3.5, it comprises all Railway Freight Terminals (RTF) located in district of the state are functioning as warehouse (hub) connected to multimodal logistics park via railways. At all railway goods shed terminals, a warehouse (hub) receive or distributes goods, from or to a network of DWC (spokes), resulting in numerous hub-and-spoke system designs.

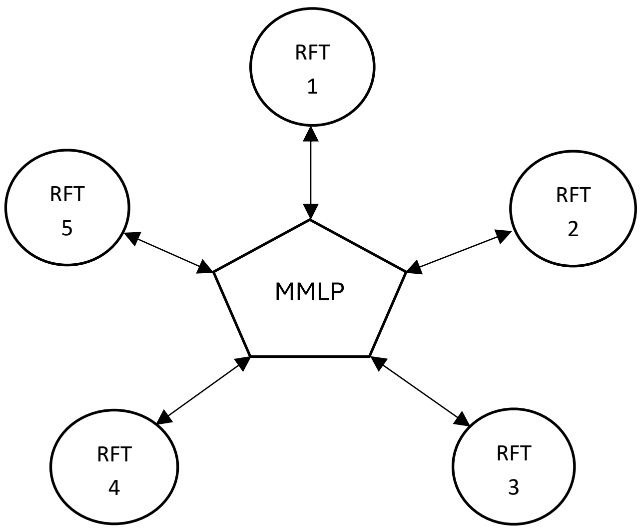

Fig. 3.5: Star infrastructure network

In the transit process where a company is undertaking a journey to DWC in a neighboring state, the transporter employs a combination of two networks, namely line and ring, in its route configuration. This approach is undertaken to ensure the efficient delivery of goods within a reduced timeframe and at a reduced cost. In the context of extensive distance travelled, such as the transportation of goods from the northern to southern regions of India, the incorporation of a line and star infrastructure network connecting DWC in one state to Indian freight trains, and subsequently to DWC in another state within a different state of India. This approach serves to mitigate the necessity for long-haulage trucks and corresponding costs , thereby reducing the overall expenses incurred by 3PL or 1PL companies during such protracted logistics processes.

3.2.4 1PL and 3PL in Logistics

First-Party Logistics is a model in which businesses manage their own transportation and distribution internally, ensuring full control but requiring substantial investments in infrastructure, personnel, and fleet management. This model framework is best suited for companies with extensive logistics expertise and the financial capacity to maintain an independent supply chain. They have their own private store to store the inventory, and when logistics department receives an order and details of consignment movement for transferring goods to DWC via a pertinent commercial vehicle. And in contrast, if the company chooses to outsource that is, 3PL for providing logistics functions, 3PL entities offering services to manage multiple logistics services for their clients as independent businesses separate from both the buyers and sellers. The sector consists of independent companies which assume part of the logistics tasks from both buyers and sellers. 3PL providers offer a range of services categorized into basic, value-added, and integrative. Basic service providers handle core functions like warehouse management, order processing, fulfillment, and selection of Local transporter which then contact truck owner for consignment. The Value-added service providers extend their offerings beyond basic functions by providing services such as shipment and order consolidation, which includes receiving orders and managing e-way bill details for consignment movement. These logistics integrators assume complete responsibility for essential supply chain operations. Their services include managing replenishment and order-filling and handling product returns.

3.2.5 Commercial vehicle selection

The employment of outdated vehicles with limited carrying capacity is one of the causes of India's road-based freight transport's inefficiencies. Small truck drivers in India are unable to purchase new, larger, and better trucks. To optimize utilisation of trucks by load matching . The given Table 3.4 guide for Vehicle selection for different network structures. Selecting the right commercial vehicle is shaped by a range of factors, with particular emphasis on the type of loading material and its weight, payload capacity, Fuel price / Per Unit Consumption Rate for EV, seasonality variation and geographical data of routes, Shipping method like FTL , LTL , PTL , where in FTL the entire truck is dedicated to a single shipment and in LTL, many shipments from different entities are combined to fill the entire truck and more cost-effective for smaller shipments but in PTL the trade-off is between FTL and LTL. This entails sharing a trailer with other clients without making additional stops for loading or unloading. Therefore, proper selection of goods carrier vehicle will reduce the number of trips the vehicle must travel to deliver the goods. Enhancing these selection procedures will lead to: A decrease in idle running Improved load factors and Increased use of vehicles.

Table 3.4: Guide for Vehicle selection for different infrastructure network

Structure type	Vehicles selection
Line network	LMV, containerised commercial Truck, L5N category Vehicle, N1 category vehicles.
Ring network	28ft /32ft containerised commercial Truck, containerised commercial Truck, HMV Transport Truck (T4)
Star network	22 ft HMV Transport Truck , 24-28 ft HMV Transport Truck commercial, containerised commercial Truck (N3).

3.3 Fuel Efficiency Optimisation

Fuel efficiency optimization and rational selection of suitable fuel types are of primary importance in reducing spending and environmental negative impacts reserved for road freight transportation. Fuel efficiency has greatly improved through innovations in vehicular technologies of optimised engine and lightweight materials like carbon fibre. Additionally, the integration of intelligent transportation systems and API of GIS software allows for making routes in real time to minimise unnecessary fuel costs and idle time.

The transition from traditional fossil fuels to alternative energy sources like biofuels (E20 and E100), compressed natural gas (CNG), flex fuel, electric batteries, and hydrogen fuel cell trains and trucks, which further cut down the carbon emissions. Long-haul freight can be operated through the use of E-fuels produced via renewable energy sources, with reduced emissions and compatibility with pre-existing infrastructure as shown in table 3.5.

Table 3.5: Fuel to cut down in the carbon emissions

Fuel Type	Carbon Emission Reduction Compared to Petrol/Diesel	References
E20 (20% Ethanol, 80% Petrol) / E 100 (100% ethanol)	17% - 80%	Suarez et al., (2024) , (Mohammed et al., 2021), Chaudhary & Subramanian, (2022)
CNG (Compressed Natural Gas)	20-25%	Rotaru et al., 2022), (Sun et al., 2024)
Electric Vehicles (EVs	60-100% (depends on electricity source)	Tetik Kollugil et al., (2024), (L. Zhang et al., (2025)

3.4 The Technological applications in cost reduction of road and rail freight transportation

To achieve real-time coordination and monitoring within India's road freight transport system, a multi-faceted technological approach is necessary. The following technological applications have been identified as key contributors to these line, ring, and star infrastructure networks , which will have discussed further in this section.

3.4.1 Transport Management System (TMS)

An enterprise transportation management system serves as application program that helps companies organize logistics operations starting from the shipment origin until delivery at final destinations while maximizing operational efficiency. The system provides with complete supply chain oversight which helps you optimize operations with dispatch generation for road transportation while improving stakeholder partnerships and enhancing critical decision-making processes. TMS enables optimised route planning, significantly reducing transportation costs and delivery times.

Enhanced collaboration is attained by merging with ERP and WMS to boost stock control and order completion. Modern TMS solutions utilise mobile and web interfaces for real-time tracking by lorry receipt number, GPS, etc. and fleet management of , enhancing user experience as discussed by Emek et al., (2024). Automation of processes minimises manual errors and enhances decision-making capabilities, leading to improved operational performance as discussed by Quiroga-Amaya et al., (2024).

Transportation management systems provide enhanced features and functionalities, such as load consolidation, which maximises container utilisation and lowers transportation costs by merging multiple orders into a single shipment. Additionally, they offer reporting and analytics, allowing access to comprehensive dashboards and reports for insights into transportation costs, key performance indicators, and trends. Automate documentation and enhance security through digital proof of delivery (POD) and electronic logging devices (ELD). The adoption of cloud-based TMS solutions has further improved scalability, accessibility, and cost efficiency, allowing organisations of all sizes to optimise their transportation networks. Ultimately, a well-implemented TMS contributes to a more resilient, cost-effective.

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3.4.2 The Internet of Things (IoT) integration in road and rail freight transportation

Cargo transportation utilizing road and rail infrastructure is witnessing the advent of a new transformative technology, the IoT, which promises to maximise operational efficiency while providing instantaneous data tracking and optimized managerial responses and cloud based fleet management. Among the domains where IoT applications are prevalent, we focus on bringing vehicles, cargo, and infrastructure together through a network various sensors and devices are employed to gather, analyse, and transmit data. Telematics systems in vehicles enable remote diagnostics by identifying potential malfunctions or faults and these on-board diagnostics systems 2 (OBD-2) as discussed by Chen et al., (2011) and also discussed that IoT technologies employed to acquire real-time operational data from vehicles and status of various vehicle subsystem. OBD-2 when a problem is detected, the vehicle's computer stores a Diagnostic Trouble Codes , which is a code that identifies the particular problem is identified, and the vehicle data is transmitted to cloud-based platforms, where it is analysed to produce notification and recommend appropriate corrective measures. IoT enables real-time monitoring of shipment, vehicle performance and predictive maintenance to eliminate delays and minimising costs. The shipment monitoring enable the observation and assessment of internal container conditions by using sensors like temperature , pressure , humidity, light, accelerometer, gyroscope motion, tilt, etc. IoT devices can also be used to improve safety in trucking and freight train operations by keeping track of driver activity, behaviour, health or conditions to ascertain whether something is amiss and recommend solutions to prevent an accident and enabling automated safety features such as collision avoidance. The Advance Driver Assistance System level 3 (ADAS -3) could be considered a cutting-edge solution that is tailored specifically for heavy commercial vehicles, meeting the demands of long-haul trucks by providing conditional automation. The Use of RFID in Indian railways Tagging in Wagons and Coaches for Identification and Tracking/Tracing of Assets. Additionally, real-time location tracking of a transportation fleet system uses GPS technology is utilized to monitor the real-time location of a vehicle and to generate timely alerts send to manager in case of deviation in planned routes, so that remedial action can be taken. The research notes that the IoT devices and cloud based services can further enhance the capabilities of cargo vehicles, allowing for cooperative data sharing and real-time updates on vehicle or freight train status and cargo conditions to its stakeholders. Therefore, leads to decreased transit time, accidents and costs in freight transportation.

3.4.3 AI integration in road and rail freight transportation

In recent years, artificial intelligence have been integrated Within the domain of road and the transport of cargo by rail as a subject of great interest. Artificial Intelligence (AI) will completely transform road and rail freight transportation. They are developed to predictive maintenance, route planning, demand forecasting and autonomous trucks and trains. The Dynamic route planning based on current traffic conditions, time of day, weather, fuel stations, toll plaza, road congestion levels, even historical traffic patterns and delivery schedules, is possible by Multi-Agent Reinforcement Learning or Reinforcement learning (RL) as discussed by Qin et al., (2019). RL-based routing in congested networks significantly improves efficiency compared to shortest-path methods, particularly in dynamic traffic conditions to minimise fuel consumption and corresponding cost and generation of alternate routes study by Cox et al., (2013). Predictive maintenance powered by AI tools leveraging Supervised and unsupervised learning-based methods are available for analysing large datasets collected from vehicle telematics and historical performance metrics to determine when maintenance is needed for a vehicle by assessing sensor data, minimising downtime and breakdown thus extending vehicle lifespan and operational time. Furthermore, Computer vision stands as a revolutionary technology within road and rail freight operations that delivers innovative methods to boost operational effectiveness while protecting safety and reducing environmental impacts. The CV systems for road freight is used to detect vehicle around it, then analyse driver actions together in real time to minimise accidents while protecting freight cargo from damage. The implementation of CV delivers important rail freight benefits through Computer vision systems that monitor the condition of train wheels and tracks in real-time, identifying defects like cracks or missing bolts and anomaly detection capabilities. By automating the inspection process, computer vision reduces the need for manual checks, speeding up operations and reducing downtime. This helps to prevent derailments and ensures the safety of rail operations, which both raise operational stability and lower maintenance expenditures. Now research by Bahga & Madisetti, (2013) revels that implementation of AI in shipment monitoring is the analysis and interpretation of data on the environment conditions in the container for Frozen, Refrigerated Perishable goods truck, where alerts can be raised to the driver and the distributor about the transit conditions , such as container temperature and humidity levels going out of the allowed limit, for instance corrective actions can be taking before damaged, using the AI which is applying Autoencoders , Isolation Forest algorithm as discussed by Neloy & Turgeon, (2024) and Reinforcement Learning ML model. Overall, integrating AI into freight transportation not only modernizes transport in logistics but also sets a new standard for efficiency and customer satisfaction in the industry. The fig 3.2: showing the formation of AI system for road and rail freight transportation.

3.4.4 Unified Logistics Interface Platform (ULIP)

India's freight system is unregulated and unstructured. Currently, in India, many logistics companies(3PL) don't own any commercial vehicles that can be used to transport goods or cargo of manufacturers, or producers from one place to another. Subsequently, these logistics companies have contracts with freight forwarding vendors and agencies which have partnerships with regional transporters. These regional or local transporter then have some truck owners working with them. These truck owners don't have any links to logistics companies. There can be the chances of truckload theft thus causing huge losses to manufacturers and distributors. Lack of Real-time information and tracking of cargo trucks can decrease the efficiency of operations. In India, 5% of companies like DHL, etc. have their own trucking services hence having structured logistics systems. But the remaining 95% of companies don't have a standard approach and run their transportation system in an unstructured manner. So, ULIP is the solution to these problems. The Unified Logistics Interface Platform is a combined platform for data communication among government and private institutions that are directly or indirectly associated with the Indian Logistics ecosystem and reduce the cost of logistics in India. It is democratizing information available with various Govt. systems for a transparent and competitive Logistics ecosystem. It is API based data exchange between the stakeholders to enable innovative approaches in improving India's Logistics sector. ULIP is utilized to develop a nationwide integrated logistics network for total visibility and optimal deployment of different transport modes and supply data that can be harnessed by the stakeholders for easing complex tasks like compliance, paperwork, certifications, and endorsements, which were usually time-consuming, difficult to manage appropriately, and needed to track consignment on multiple portals. So, with ULIP all the information like Shipping Bill, Railways FNR, Airway Bill, LR, E-way Bill, etc. is presented on single window of ULIP. There is always difficulty in manual verification of drivers & vehicles by manufacturers or distributors and without ULIP, the increased risk of non-compliant transportation can lead to serious consequences, including hefty fines, delayed delivery, and seizure of goods. Therefore, ULIP will instantly verify commercial vehicles and help increase productivity, efficiency, and effective movement of goods and reduce logistics costs & time. Currently, the platform integrates with 43 systems from 11 ministries via 129 APIs, covering over 1800 data fields. Another platform contained in ULIP is the Logistics Data Bank (LDB). LDB operates as a tracking system that monitors the movement of containers from ports to their different hinterland locations which include ICD, toll plazas, railway stations, both during domestic and international movements. Real-time tracking through IoT and Big Data and Cloud-based solutions. As a cloud-based logistics tracking system it functions as a single visualisation platform where users can track containers through their identification numbers. Furthermore, one important aspect of ULIP is FOIS which provides consumers with convenience, speed, and ease by allowing them to register and book indents for rakes and waggons online. It can track and monitor the movements of goods trains. The information is subsequently published to end users via ULIP. It has now evolved into a comprehensive goods train management module that can handle billing and revenue collection. It has contributed significantly to increased waggon productivity on Indian Railways, and the goal is to use the data to boost productivity and customer service even further, meeting the needs of a rapidly rising economy. The ULIP Can be connected to existing transportation management systems of the logistics company so that real time information of their transit goods and transporter can be shared easily. Thus, increase transparency and visibility in the entire fleet management to reduce empty movement and waiting time.

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3.5 Intelligent freight transportation system

The Intelligent freight transportation system's architecture in Fig. 3.6 operates through a multi-layered, data-driven framework that integrates various stakeholders, digital systems, and logistics applications to enhance efficiency, security, and transparency across multimodal transport infrastructure networks. This platform functions as a virtual gateway, serving both as a conduit for exchanging data and as a central hub for managing transportation and supply chain processes. The process flow begins with, at the highest level, a collection of governmental and regulatory systems and various national agencies connected to a unified logistics platform.

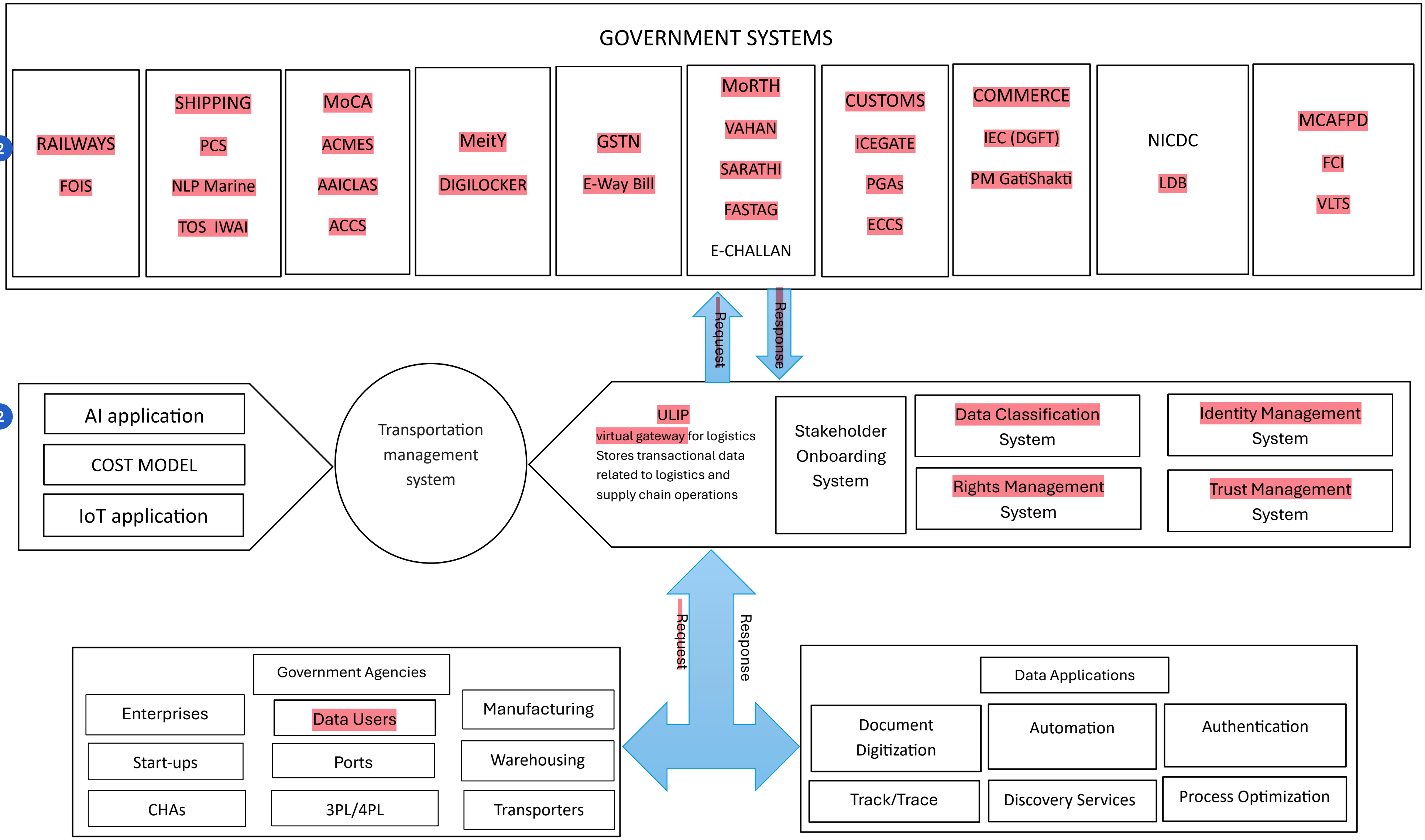

Fig. 3.6: Architecture of Intelligent freight transportation system

The private stakeholders (e.g., third-party logistics providers, warehouses, and transporters) have to sign in to ULIP and then receives this data and channels it into different subsystems: a Stakeholder Onboarding System, which authenticates and registers new participants in a Data Classification System, which organises the data into structured formats; and an Identity Management System, which ensures secure handling of user identities and credentials. In tandem, a Rights Management System and a Trust Management System govern data access and usage permissions, preventing unauthorised access while maintaining a reliable environment for data exchange. Within the platform, the stakeholder requests information and certification in real time and then gets a response from government agencies and other data users.

IFTS supported from AI applications, IoT applications, and the cost model applications through (Application Programming Interface) APIs in TMS, which will integrated into the logistical framework, enabling users to calculate transportation costs under various scenarios. Other functionality of ULIP such as document flow, track/trace of cargo vehicle, and authentication services will be performed. The overall outcome is a coordinated and digitalised logistics environment that standardises information exchange, planning fleet journey, transport cost calculations, and streamlines procedures for various government agencies, logistics providers.

3.6 COST MODEL DEVELOPMENT

The predominant approach employed by the 1PL company and 3PL freight forwarder to accomplish transport assignments involves the utilisation of bottom-up estimating. The Bottom-up estimating in road and rail transportation involves detailed analysis and modelling to achieve accurate cost predictions. It consists of breaking down the transportation process to the lowest level, which is fixed, variable costs and Miscellaneous Costs (the smallest component), and then aggregating all related costs by calculating the cost of each component and then adding them to find the overall cost of transportation in transit. As illustrated in Table 3.6, These costs is incurred by logistics companies when they undertake freight transport. The subsequent three cases illustrate the development and implementation of the cost model framework.

Table 3.6: Costs associated with road and rail freight transportation

Fixed costs	Variable costs	Miscellaneous Costs
Cargo vehicle's driver salary per trip d	Driver Allowances e	Indian Railway Indent Booking charges B
Support staff salary d_S	Fuel cost F	Accident Costs ε
contract driver wages per trip d_e	Cargo insurance C_i	Transporter margin % γ
Lease carrier vehicle Cost V	Terminal handing charges per trip t_h at Railway freight terminal	
Administrative charges per trip x	Total Loading/unloading Labour Costs per trip C_H	
Container Cost per trip C_C	Warehousing charges for storing q	
GST G	Packaging cost ω	
Spare part cost of cargo vehicle s	Parking Cost per trip P	
	Maintenance & repair Cost M	
	Total toll charges per trip T	
	Special Handling Charges ∂	

The primary units used to measure goods in road freight transport are tonne-kilometer (tkm) and the Road-Rail freight transport rate having unit Rupees per metric ton kilometer as discussed by Heizer, J., Render, B., Munson, C, (2020) The breakdown of cost components is respectively stated below.

- Total cost of transportation C_T
- Total Fixed cost C_F
- Total variable cost C_v
- Distance travelled D in km
- Type of fuel f_T
- Mileage m varies with types of fuel , type of Truck and uses condition
- Packaging cost can be considered per tonne, per pallets or per box.
- Terminal handling charges can be considered per tonne or per pallets
- Warehousing charges can be considered per cubic foot or per pallets
- Weight of goods W in Tonne
- Transit time t
- Cargo insurance is quantity dependent variable C_i
- Fuel cost , $F = f \times \frac{D}{m}$; fuel price / liter = f
- Number of Trips N

- Cost of Cargo Handing per trip is calculated as:

$$C_H = \sum_{k=1}^{n} c_{hk}$$

where, k Where is the number of warehouses in which unloading and loading of goods are performed during a trip and c_{hk} is the loading and unloading labours charges per 100 kg or box at warehouse.

- $$\text{Revenue} = \text{Road Freight Transport Rate} \times \text{Distance (km)} \times \text{Total weight of load (tons)} \times \text{Number of Trips} \times \left(1 + \frac{\textit{Transporter margin}}{100}\right)$$

$$\text{Revenue in any network} = C \times D \times W \times N \times \left(1 + \frac{\gamma}{100}\right) - \varepsilon$$

$$\text{Road Freight Transport Rate in any network} = C$$

3.6.1 Application of the line infrastructure network within a limited region in Delhi

In the context of a hypothetical transport enterprise (3PL or 1PL) operating in the proposed structured Road-Rail freight transportation system. One can envisage a particular scenario whereby the logistics company is engaged in the transportation operation with line infrastructure network, this can be applicable across any transport activities conducted between the DWC and the Multi-Modal Logistics Park located , or alternatively, from the DWC to the retail outlet. The line infrastructure network works best in FTL Shipment. The journey commencing from an Inland Container Depot located in Tughlakabad within the jurisdiction of Southeast Delhi district, and concluding at a retailer situated in the Chhatarpur area of the southern segment of Delhi district as shown in fig 3.7. The driver is equipped with Intelligent freight transportation system, which can provide navigation application such as NaviMaps or any Geographic information system (GIS) application link by API, that is adept at providing the most efficient routes along with the estimated time required to reach the designated destination, fuel station , traffic condition in real time. Upon the delivery of the load by the transporter at either the retailer or the DWC, the relevant confirmation details are updated for all relevant stakeholders via ULIP.

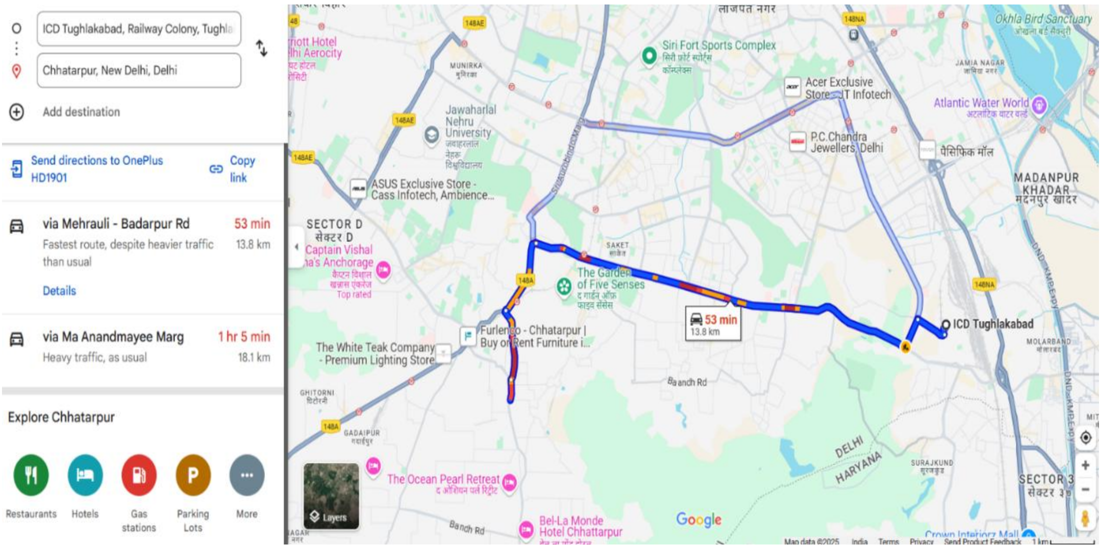

Fig. 3.7: Line infrastructure network within a limited region in Delhi (source: google maps)

The logistics company can accept the empty run cost, but if it delivers the load at DWC/MMLP, then the transporter can get the load for the return trip through TMS and ULIP , resulting in a profit. So Presented below is the cost estimation that pertain to a line infrastructure network of cost model application. It is essential to note that there are no toll plazas situated along the designated short transport route, but longer route may have toll plaza. Thus, in this case toll charges is not applicable when calculating the total operational cost associated with this transportation endeavor. Hence, we can compute the entire cost of transportation in the line network per trip using the following equations as discussed by Heizer, J., Render, B., Munson, C, (2020):

Total cost in line infrastructure network C_{Tl}
Fixed cost in line infrastructure network C_{Fl}
Total variable cost in line infrastructure network C_{vl}
Empty run cost in line infrastructure network during return journey $C_{el} = F + M$
Transporter margin % γ

i. own vehicles with own drivers

$$C_{Tl} = C_{Fl} + C_{vl} + C_{el}$$

$$= [\, d + d_S + C_C + G + s + x \,] + [\, F + e + P + C_H + C_i + \omega + t_h + M + q + \partial] + C_{el}$$

ii. Rented vehicle with external driver (outsourcing)

$$C_{Tl} = C_{Fl} + C_{vl}$$

$$= [V + d_e + C_C + G + s + x] + [F + e + C_H + C_i + \omega + t_h + M + P + q + \partial]$$

iii. Road Freight Transport Rate in line infrastructure network , $C_L = \frac{C_{Tl}}{W \times D}$ in Rupees per ton per Kilometer

iv. Revenue in line network $= C_L \times D \times W \times N \times \left(1 + \frac{\gamma}{100}\right) - \varepsilon$

The equation (i) gives the total cost in rupees per trip when operated in a line infrastructure network for the 1PL and 3PL companies that have their own vehicles with their own drivers. But the equation (ii) provides the total cost in rupees per trip when operated in a line infrastructure network for the 1PL and 3PL companies that have their rented vehicles with external drivers, which means these companies hired the local transporters for the transportation process . The equation (iii) provide the Road Freight Transport Rate in Rupees per Ton per Kilometer. Through equation (iv), one can ascertain the revenue accrued throughout the entire journey of a shipment of goods, commencing from point of starting to the last delivery location within the line infrastructure network.

3.6.2 Application of the Ring infrastructure network in Delhi

In reference to the ring infrastructure network, which will be strategically established by creating a DWC in each Legislative Assembly constituency (AC) that is in close proximity to the borders of Delhi's state territory, as it can be seen in Figure 3.8, this encompasses the Assembly Constituencies namely AC-1, AC-7, AC-8, AC-35, AC-34, AC-36, AC-45, AC-46, AC-52, AC-53, AC-54, AC-56, AC-62, AC-68,AC-70 and AC-2. The selection of these particular locations was meticulously determined based on the potential for enhanced strategic business opportunities that could arise in conjunction with neighbouring states. Regarding these DWCs, the cargo vehicles are capable of transporting goods to various other states or conversely, bringing goods from other states to Delhi, all in a well-structured manner that minimizes costs significantly. In the context of a hypothetical transport enterprise (3PL or 1PL) operating in the proposed structured Road freight transportation system. One can envisage a particular scenario whereby the logistics company is engaged in the transportation operation with Ring infrastructure network through the Intelligent freight transportation system. The Ring infrastructure network is suitable for LTL Shipment and there are frequent truck loading and unloading stoppages at various DWCs in the ring infrastructure network. The corresponding confirmation details of all delivery and pickup points are updated for all respective stakeholders via ULIP. Because the vehicle makes many stops, this case allows for more flexibility in shipping schedules, including last-minute or unexpected shipments. Furthermore, every stakeholder can Track/Trace and authenticate their fleet process easily with ULIP. it is imperative to recognize that toll plazas may be located along the planned transportation route. Relevant data regarding these toll facilities can be procured from the TMS and ULIP platform of Intelligent freight transportation system. Consequently, when goods are transported to nearby states, toll charges and increased handling fees must be incorporated into the overall calculation of Toal costs. Hence, we can compute the entire cost of transportation in the Ring infrastructure network per trip using the following equations as discussed by Heizer, J., Render, B., Munson, C, (2020):

Total cost of transportation in ring infrastructure network C_{Tr}
Fixed cost in ring infrastructure network C_{Fr}
Total variable cost in ring infrastructure network C_{vr}
Empty run cost in ring infrastructure network $C_{er} = F + M + T$
Transporter margin % γ

i. Own vehicles with own drivers

$$C_{Tr} = C_{Fr} + C_{vr} + C_{er}$$
$$= [d + d_S + C_C + G + s + x] + [F + P + C_H + T + e + C_i + \omega + q + M + y + \partial] + C_{er}$$

ii. Rented vehicle with external driver

$$C_{Tr} = C_{Fr} + C_{vr}$$
$$= [V + d_e + C_C + G + s + x] + [F + C_H + e + C_i + \omega + T + M + P + q + \partial]$$

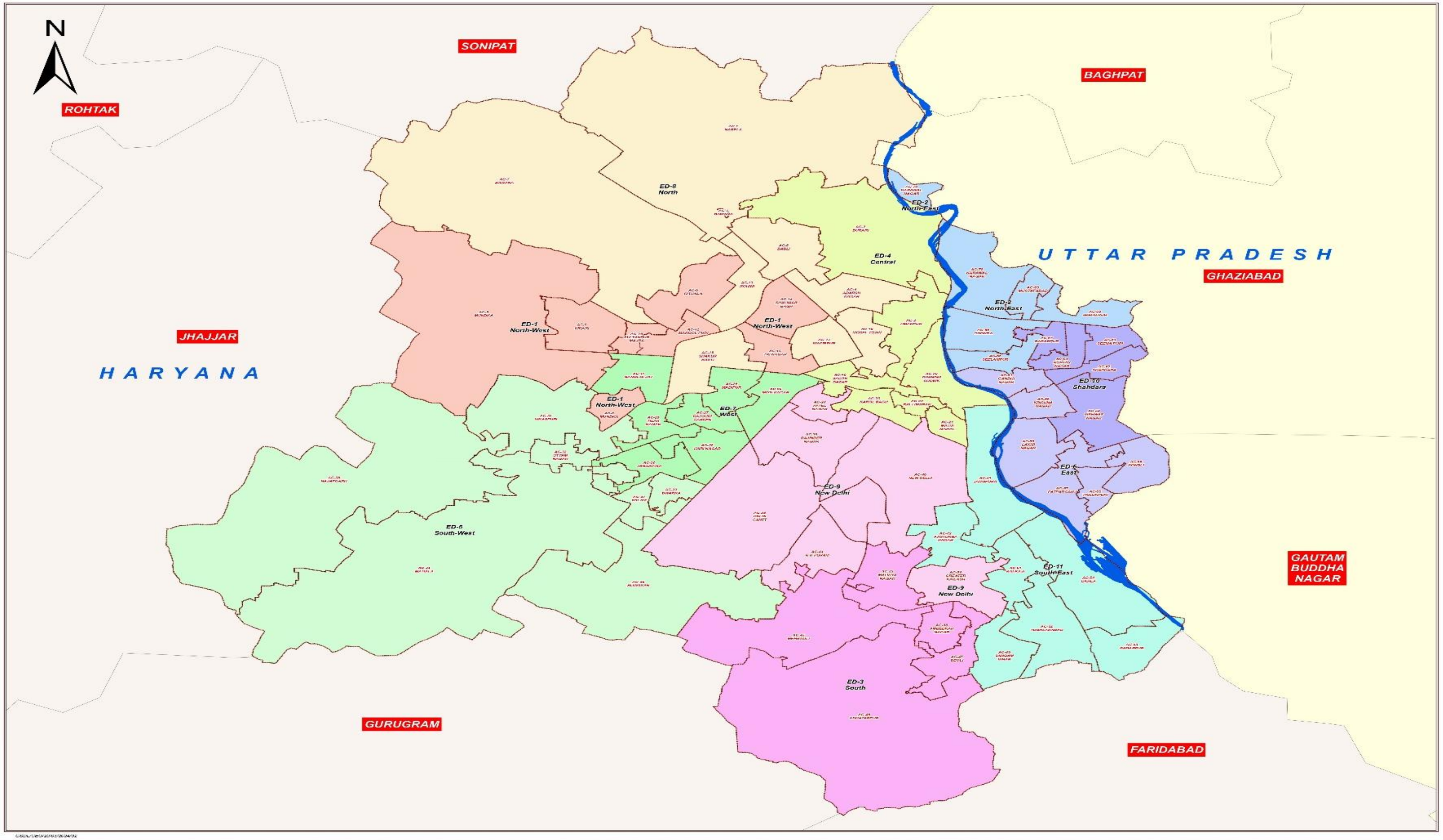

Fig. 3.8: Map Of Delhi's District with Assembly constituency at Delhi's boundary forming Ring infrastructure network (source: https://dmnewdelhi.delhi.gov.in/map-of-district/)

iii. Road Freight Transport Rate in ring infrastructure network , $C_r = \frac{C_{Tr}}{W \times D}$ in Rupees per ton per Kilometer

iv. Revenue in ring network $= C_r \times D \times W \times N \times \left(1 + \frac{\gamma}{100}\right) - \varepsilon$

The equation (i) delineates the comprehensive cost expressed in rupees per trip when executed within the ring network for both 1PL and 3PL enterprises that possess their own vehicles and employ their own drivers. Conversely, the equation (ii) articulates the comprehensive cost in rupees per trip when conducted within the ring network for the 1PL and 3PL enterprises. The equation (iii) provide the Road Freight Transport Rate in Rupees per Ton per Kilometer of ring network. And the equation (iv) can be used to calculate the revenue generated during the complete journey of goods from its origin point to its final delivered location within the state and neighbouring state, in ring network.

3.6.3 Application of the Star infrastructure network within NCR Delhi

In the context of a hypothetical transport enterprise (3PL or 1PL) operating in the proposed structured Road-Rail freight transportation system. One can envisage a particular scenario whereby the logistics company is engaged in the transportation operation with star infrastructure network through the Intelligent freight transportation system. The star infrastructure network is suitable for PTL and FTL shipping methods. In our planning efforts, as seen in Fig 3.9, the Delhi railway map, which is mainly considered for making MMLP and goods shed. we posit that the establishment of the Multimodal Logistics Park (MMLP) will take place at the strategically significant Hazrat Nizamuddin Railway Station, which is located within the bustling metropolis center of Delhi. Moreover, this site is in close proximity to the banks of the Yamuna River, thereby enabling the potential for the utilization of inland water transport (IWT) as a viable means of logistics. we have meticulously designed a star infrastructure network that encompasses all District Warehouses and Centers (DWCs) situated at the Railway Freight Terminals within the state known as RFT , with these facilities being intricately linked to a central hub or multimodal logistics park through an extensive network of railways , particularly as this system is also directly integrated with the FOIS online portal service in ULIP and Intelligent freight transportation system. Consequently, the transition of bulk or long-haul freight operations to rail transportation has the capacity to significantly diminish the overall fuel consumption associated with the road freight transport. For the operators of road freight services, the reduction of congestion on roadways yields a notable decrease in idle time, which in turn results in lower emissions and reduced fuel expenditures. The road freight transport serves an major function during first mile of the logistics chain by facilitating the movement of goods to and from these strategically located RFT hubs. For instance, there exists a particular goods-carrying truck that originates from DWC, the DLF Kirti Nagar Industrial Area, which is located in the Northwest District of Delhi, and this truck is making its way towards the SSB (SHAKURBASTI) Railway goods shed terminal (RFT) with the intention of transferring various goods onto a freight train. This transfer is essential as it allows the aforementioned freight train to subsequently transport the goods to the MMLP, which is strategically situated at the Hazrat Nizamuddin Railway Terminal. Thus, Indian Railways' dedicated freight corridors is utilised to reach the destination Railway goods shed terminals or MMLP. This entire process is coordinated by FOIS online portal where the company booked a wagon or rake as per their need and paid the Indian Railway Indent Booking charges. Then the unloading the load from cargo container and load it into truck for delivering to DWC in the Other states of India using Line infrastructure network. This allows items to reach at their destinations at far lower prices and in much less time and carbon emission than traditional road transit techniques. In the context of the star infrastructure network, it is essential to note that there are no toll plazas situated along the designated short transport route within the state, and this critical information can be sourced from the ULIP. Thus, in this case toll charges is not applicable when calculating the total operational cost associated with this case.

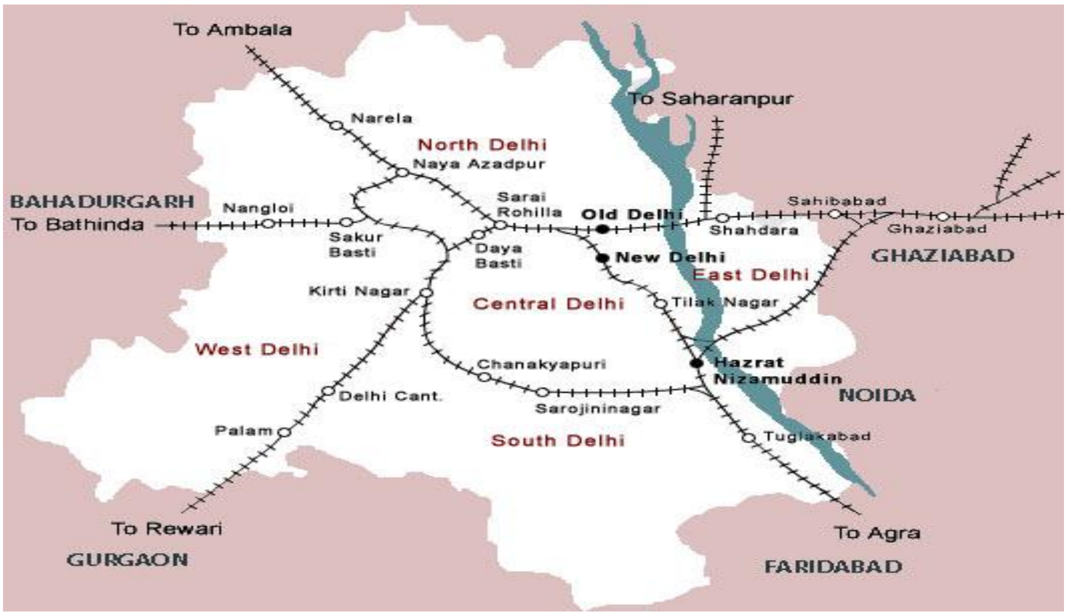

Fig. 3.9: Indian Railways network in Delhi NCR (source: https://www.mapsofindia.com/maps/delhi/railway.html)

Hence, we can compute the entire cost of transportation in the star infrastructure network per trip using the following equations as discussed by Heizer, J., Render, B., Munson, C, (2020):

Total cost of transportation in star infrastructure network C_{Ts}
Fixed cost in star infrastructure network C_{Fs}
Total variable cost C_{vs}
Empty run cost in Star infrastructure network $C_{es} = F + M$
Transporter margin % γ

i. own vehicles with own drivers

$$C_{Ts} = C_{Fs} + C_{vs} + B + C_{es}$$
$$= [\, d + d_S + C_C + G + s + x \,] + [\, F + P + e + C_H + C_i + \omega + t_h + \partial + M \,] + B + C_{es}$$

ii. Rented vehicle with external driver

$$C_{Ts} = C_{Fs} + C_{vs} + B$$
$$= [\, V + d_S + d_e + C_C + G + s + x \,] + [\, e + F + C_H + C_i + \omega + t_h + M + P + q + \partial] + B$$

iii. Road-Rail Freight Transport Rate in star infrastructure network , $C_s = \frac{C_{Ts}}{W \times D}$ in Rupees per Ton per Kilometer

iv. Revenue in star network $= C_s \times D \times W \times N \times \left(1 + \frac{\gamma}{100}\right) - \varepsilon$

For the last case, the equation (i) provides the expenditure in rupees per trip when functioning within a star infrastructure network for both 1PL and 3PL entities that possess their own vehicles along with designated drivers for road cargo transport vehicles to reach RFT or MMLP , and when the goods are transferred to respective freight trains, the rail transportation costs associated with carrying the goods to the destination, which is paid by these companies to Indian Railways of the Govt. of India are added in it. Conversely, the equation (ii) elucidates the total expenditure in rupees per trip when operating in a star infrastructure network and both 1PL and 3PL entities utilise rented vehicles with external drivers for road cargo transport vehicles to deliver the goods to RFT, and from there the load or goods are transferred to freight trains so the rail freight transportation costs associated with carrying the goods to the destination, which is paid by these companies to the Indian Railways of the Govt. of India, are added in it. The equation (iii) provide the Road Freight Transport Rate in Rupees per Ton per Kilometer. And the equation (iv) is able to ascertain the revenue accrued throughout the entirety of a shipment's journey, commencing from its starting point to its final stop in another state of India.

3.7 Comparison between star infrastructure network and ring infrastructure network

The star and ring infrastructure networks are two fundamental models in the framework of freight transportation systems. Each network has unique structural, operational, and economic characteristics that influence its suitability for different freight logistics scenarios. The table 3.7 shows the comparison of star infrastructure network and ring infrastructure network that can be tabulated around several key features.

Table 3.6: Comparison of star infrastructure network and ring infrastructure network

Feature	Star ring infrastructure networks	Ring infrastructure networks
Network structure	Central MMLP connects all RFTs	Each DWC at peripheral of the connects to two adjacent DWCs forming a closed loop
Modes	HMV, LMV vehicle and Railway freight train	HMV, LMV, L5N and N1 vehicles
Shipment method	FTL and PTL shipment	Less than truck load (LTL) shipment
Efficiency	Enables economies of scale in transport due to high volume of load and efficient for long-haul freight transportation	Efficient for freight transportation within a state
Cost Implications	Lower if existing structure are arranged in proposed star infrastructure network but High capital investment for new MMLP	Minimal capital allocation for the advancement of new roadway construction in alignment with the ring infrastructure framework.
Management	Centralized control and coordination can simplify overall network management from a strategic perspective	Coordination becomes complex with increasing numbers of DWC or if dynamic routing/scheduling is required across the ring network
Transit Time	Longer time due to larger distance and potential processing delays	Less time as distance travelled is least and within a states.

9

CHAPTER 4

IMPLEMENTATION, RESULTS AND DISCUSSION

4.1 Implementation- star infrastructure network

In an extensive analysis regarding the considerable distances traversed, particularly exemplified by the intricate logistics involved in the transportation of goods originating from the northern regions of India that is Delhi and destined for the southern territories, that is Indore , a sophisticated strategy is proposed that entails the implementation of a star infrastructure network with the help of the logistic company This infrastructure network, which effectively links the Distribution Warehousing Centers (DWC) situated in one state to the extensive network of Indian freight train, subsequently facilitates a seamless connection to the DWC located in another state within the diverse geographic and economic landscape of India. Such a method not only serves to significantly alleviate the dependence on long-haul trucks, which are often associated with exorbitant operational costs, but it contributes to diminishing the overall financial burdens that are typically borne by 3PL or 1PL companies involved in the management of these extended and complex logistics processes. Following the implementation of the aforementioned cost model in star infrastructure network , by the logistics company generated the below mentioned data, The table 4.1 shows the total cost (in rupees) and Road-Rail freight transport rate (Rupees per Ton per Kilometer) of Long-haul freight transportation between Delhi to Indore. The figure 4.1 demonstrates the Movement of goods in employing star infrastructure network. A comprehensive evaluation and comparative analysis of the cost implications associated with traditional long-haul road freight transportation methods versus the innovative star network approach is meticulously undertaken, employing the sophisticated analytical capabilities of the SPSS software tool to enhance the validity of the result. A flowchart depicting the Computation procedure is shown in Figure 4.2.

Fig. 4.1: Movement of goods in employing star infrastructure network

Table 4.1: Total freight transport cost between Delhi to Indore

Own vehicles with own drivers (star network)		Rented vehicle with external drivers (star network)		Long-haul freight transportation with trucks	
Total cost	Road-Rail Freight Transport Rate	Total cost	Road-Rail Freight Transport Rate	Total cost	Road-Rail Freight Transport Rate
₹ 67,850	5.874	₹ 68,650	5.944	₹ 80,640	7.982
₹ 65,300	5.654	₹ 65,325	5.656	₹ 74,650	7.463
₹ 66,470	5.755	₹ 65,820	5.699	₹ 79,350	6.870
₹ 68,900	5.965	₹ 69,732	6.037	₹ 75,000	6.994
₹ 70,450	6.100	₹ 72,650	6.290	₹ 85,000	7.359
₹ 66,750	5.779	₹ 71,300	6.173	₹ 90,050	8.797
₹ 71,200	6.165	₹ 65,930	5.708	₹ 89,200	7.723
₹ 66,300	5.740	₹ 66,410	5.750	₹ 89,000	7.706
₹ 65,600	5.680	₹ 66,522	5.759	₹ 76,000	7.580
₹ 67,000	5.801	₹ 67,450	5.840	₹ 79,400	6.974

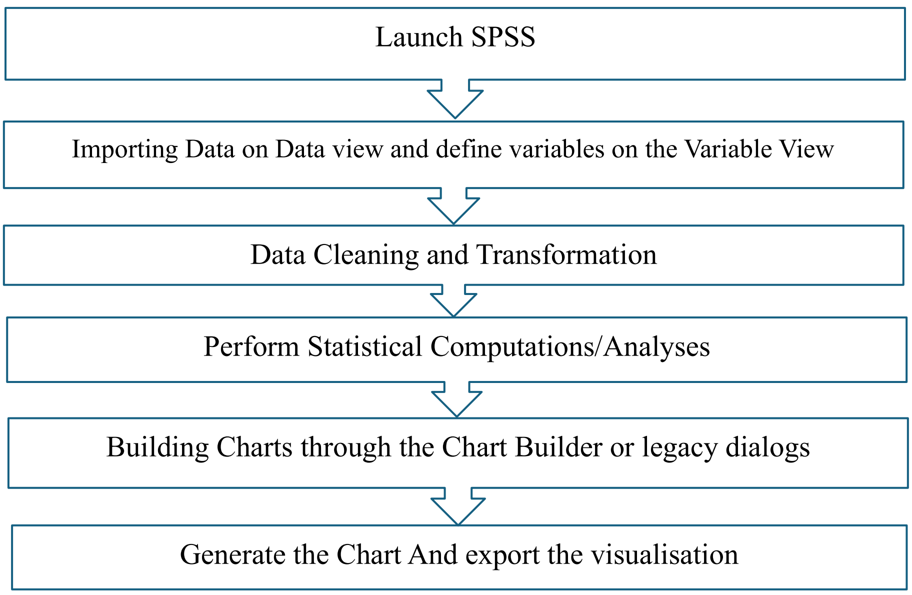

Fig. 4.2: flowchart depicting the Computation procedure in SPSS

4.2 Results

The comparison of the overall cost of transportation for Long-haul freight transport involving heavy-duty trucks following the traditional unstructured approach and using roadway in contrast to the innovative star network integrated with bottom-up cost estimating model within Intelligent freight transportation system that has been proposed for more effective cost assessment in this domain where it results in total transportation expenditures diminish by 17 to 20%. And the variability is least in own vehicle own driver ownership scenario, as shown in figure 4.3

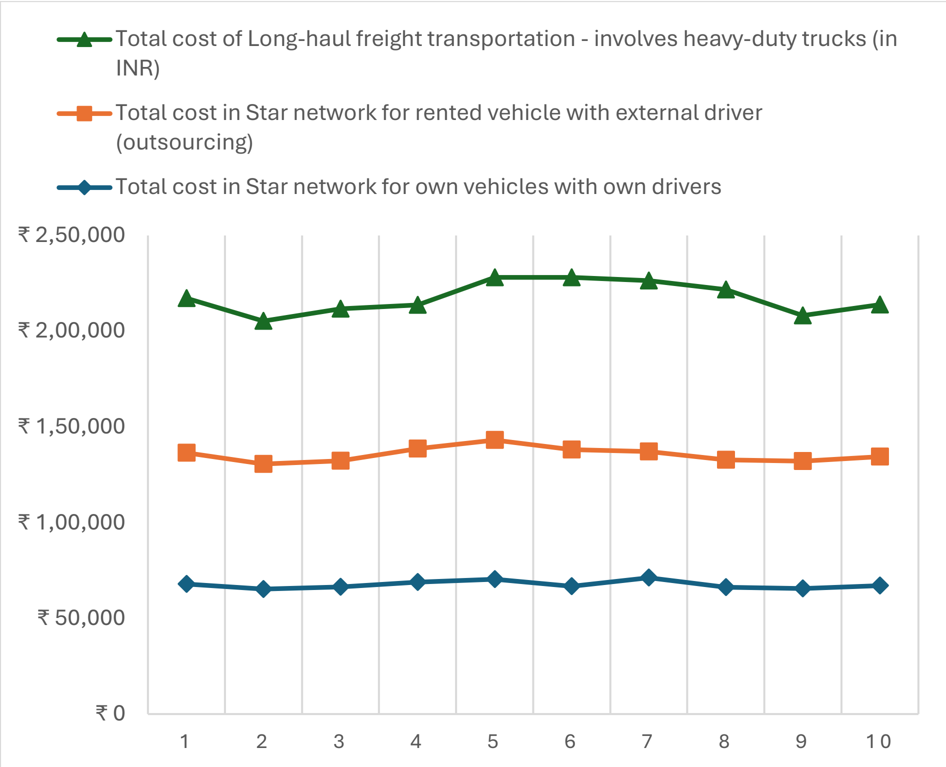

Fig. 4.3: Total transport cost (in rupees)

The figure 4.4 show the comparative analysis of the transport rate of OVOD, RVED in star network and long-haul road freight transportation. It is found that own vehicle own driver ownership scenario result in the lowest cost expense of freight transport rate. That is, the cost per metric tonne per kilometre ranges from 4.5 to 5.8 rupees , which is lesser than long-haul road freight transportation.

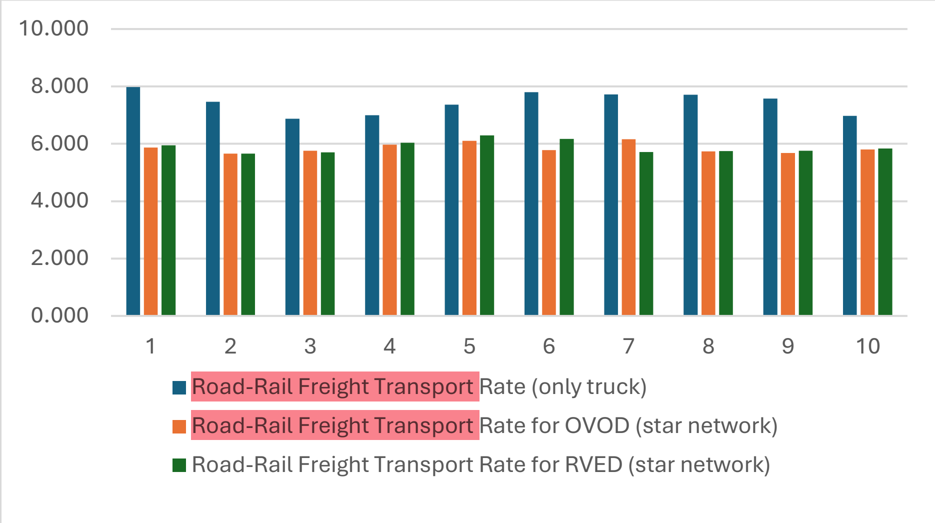

Fig. 4.4: Road-Rail Freight Transport Rate (Rs. per metric tonne kilometer)

4.3 Discussion

Based on the result of the application of the star infrastructure network using IFTS for long-haul freight transportation. The research successfully establishes a comprehensive and modular framework for estimating road-rail total expenditures of freight transport in India. The cost model decomposes the total cost into three infrastructure networks. The line infrastructure network establishes a linear, two-way flow for goods or materials; the ring infrastructure network, where DWCs are interlinked in a circular configuration to establish a closed-loop system allowing inter-district movement of commodities in the state and adjacent states in the least time at the lowest cost; and the third network, which is not specified. And the star infrastructure network in star topology that comprises all Railway Freight Terminals (RTF) located in districts of the state connected to multimodal logistics parks via railways and performs efficiently for long-haul transportation. Dynamic pricing strategies were examined in relation to factors such as fuel price volatility, seasonal demand fluctuations, road conditions, and policy interventions. A crucial aspect of these network-specific models is their explicit accounting for the heterogeneity of the Indian road freight sector. The IFTS, underpinned by ULIP, AI, and IoT, was analysed for its transformative potential. AI-enabled predictive analytics were found to be particularly beneficial in demand forecasting and dynamic route planning. IoT devices such as GPS trackers, RFID tags, and telematics systems enhanced the reliability of operations, further supporting cost reduction through preventive maintenance and fuel efficiency optimisation. The examination of the comprehensive transportation expenses and the corresponding charges in Rupees per metric tonne kilometer for OVOD and RVED within a star network indicated that the OVOD scenario will prove more advantageous in comparison to RVED over an extended duration for 1PL, owing to its lower costs and reduced transit duration. Furthermore, when a logistics enterprise engages in long-haul road freight transportation, it has been observed that both the total transportation costs and transit times are considerably elevated. Consequently, the various stakeholders involved in the decision-making process are now equipped to make informed and judicious decisions, ultimately selecting the most optimal star infrastructure network that is specifically designed for the efficient transportation of long-haul freight.

CHAPTER 5

CONCLUSION, FUTURE SCOPE AND SOCIAL IMPACT

5.1 Conclusion

The development of structured road-rail freight transportation and cost models tailored to this complex landscape is critical for improving operational efficiency and reducing overall logistics costs. This conceptual article shows the feasibility as well as the impacts that the structured road - rail transportation system can create for India's logistics landscape. A structured approach is essential, in this study we utilized a thorough literature review, the survey of logistics companies and transporters to identify the key cost factors. The costs elements are incorporated based on a Bottom-up approach to cost estimation model, so that transport costs can be evaluated accurately in rupees per metric tonne per kilometre. The cost model framework is coupled to diverse networks like line, ring, and star networks to improve efficiency in different areas. It emphasize the multimodal logistics hubs, thereby MMLPs streamline the supply chain, leading to faster and more reliable delivery alleviating road congestion. Moreover, adopting technological innovations like TMS, AI, IoT applications integrated with ULIP will demonstrate formation of Intelligent freight transportation system for better fleet management and reduction transit time. In this research work the model was applied within the Delhi region upon three cases of line, ring, and star networks with a cost model framework proposed for each. Further the cost model of the star network was implemented by a logistic company for the stipulated long distance, where it was demonstrated that a systematic and structured and regulated transportation system adopting technological innovations like TMS, AI, and IoT applications integrated with ULIP will result in better fleet management , total transport costs decrease by 17 to 20% and The cost per metric tonne per kilometre ranges from 4.5 to 5.8 rupees. Therefore, these tests will assist in determining the scalability and generalisability of the model in various logistics contexts and improved fleet management and reduction transit time, total cost and further enhance the sustainability of freight transportation in India.

5.2 Limitations

a) Future research should quantify the combined effect of different fuels used in the transport sector.

b) Consequently, a wider variety of logistics company datasets is needed for testing of the proposed cost model framework implementation in India, considering different conditions of geographical locations, and industry sectors that rely on freight transportation.

5.3 Future Scope

a) To validate the practical relevance and efficacy of the developed cost models within different industries like agriculture, manufacturing & production, E- commerce companies, etc.

b) By constructing a same structured cost model for each state in India and combining them together on a grid, we can get better connectivity among railways, roads, inland waterways, and airport transportation services to reduce time and delivery costs to the maximum possible extent.

c) The project encompasses the comprehensive and intricate development of a specialized web application that effectively integrates technologies, such as TMS, ULIP, AI, IoT, and a meticulously designed cost model that ensures optimal resource allocation and improving efficiency, transparency, real-time monitoring and automated processes in the transportation sector and significantly enabling stakeholders in developing astute, data-centric judgments.

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