# SUSTAINABLE FREIGHT TRANSPORTATION AND REVENUE MANAGEMENT MODELS

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# Abstract

Global logistics industry involves all supply chain activities such as inventory management, transportation, information flow, customer service, and order processing. In terms of revenue, the global logistics market was worth USD 8185.46 billion in 2015, and it is predicted to reach USD 15522.02 billion by 2023, rising at a CAGR of 7.5 percent from 2015 to 2024. In terms of volume, the market was valued at 54.69 billion tonnes in 2015 and is predicted to reach 92.10 billion tonnes by 2024, with a CAGR of 6% from 2016 to 2024 [1]. India is ranked as the fifth largest and one of the fastest growing economies in the world. A well-organized logistics ecosystem is believed to be a catalyst for improving the competitiveness of all areas of the economy. As a result, boosting supply chain efficacies and lowering logistics costs are critical for India to invest in strategic changes and achieve its precise goal of becoming a USD 5 trillion economy by 2025 [2]. The Indian logistics sector is worth USD 150 billion and accounts for 14.4% of the national GDP. Improving the Logistics is the foundation stone of the Government's endeavour to achieve the 'Aatma Nirbhar Bharat'. In supply chains, freight transport and logistics play a key role in the smooth movement of inputs and completed goods. One of the most difficult aspects of developing logistics networks is balancing planning decisions with sustainability. The most significant challenge in the logistics industry is the high cost of fuel that influences the transportation expenses as well.

This thesis mainly aims at efficient and effective transportation management in the freight logistics sector considering real life and complex decisions especially for the maritime industry. It emphasizes on the importance of developing decision-making models that include cargo shipment cost minimization, vehicle speed optimization, reducing carbon emissions, freight revenue maximization, and handling critical uncertainties inherent to the freight logistics operations. It studies more specifically the trade-offs that are necessary to design efficient logistics networks while considering various environmental aspects, thus improving chances

to take this step toward sustainability. Reducing bunker consumption and carbon footprint in the marine transportation is one of the major issues as it relates to sustainability. The total fuel used and carbon emissions from the vessels are strongly intertwined. There is a need to look into probable options for bunkering management and carbon emission reduction in shipping.

In the first stage, this thesis optimizes the vehicle speed for batches of vehicles while goods being shipped to customers to minimize the supply chain cost under uncertain demand and to reduce the vehicle related carbon emissions. The problem of regulating vehicle speed at each stage is disintegrated into a set of subproblems. They can be easily dealt with first approximating by dynamic programming formulation. Then a set of differential equations associated with total costs can be obtained from the formulation and solved. Furthermore, a numerical case study related to truck transportation is provided to realize the advantages of varying speed policy over fixed speed policy.

Due to a substantial growth in the world waterborne trade volumes and drastic changes in the global climate accounted for $CO_2$ emissions, the shipping companies need to escalate their operational and energy efficiency. Therefore, in the second stage, a multi-objective mixed-integer non-linear programming (MINLP) model is proposed to simultaneously determine the optimal service schedule, number of vessels in a fleet serving each route, vessel speed between two ports of call on each route, and flow of cargo considering transshipment operations for each pair of origin-destination. This MINLP model presents a trade-off between economic and environmental aspects considering total shipping time and overall shipping cost as the two conflicting objectives. The shipping cost comprises of $CO_2$ emission, fuel consumption and several operational costs where fuel consumption is determined using speed and load. Two efficient evolutionary algorithms are applied to solve the proposed problem.

Liner transportation companies are concerned about generating revenue. Operational cost cutting and increased freight revenue are the two most important factors of boosting shipping profit. The cost of bunker fuel and various other relatively fixed costs are included in the operating cost. Bunker purchasing has a direct impact on shipping profitability. With bunker fuel expenditures surpassing 60% of voyage costs, it is the most expensive operating expense for ship owners. Slight change in bunker fuel price or consumption might result in a significant change in bunker fuel expense. As a result, controlling bunker fuel usage and choosing bunkering ports are critical to lowering bunker fuel costs. The majority of freight revenues comes from transportation of containers. Considering these points, we have solved a fuel bunker management problem along with the speed optimization, schedule design, cargo flow with transshipment and fleet deployment for liner shipping networks in the third stage.

Digitalization is constantly altering company paradigms and expanding cross-border supply chain prospects. Since maritime shipping services need to exchange a huge number of papers and paperwork across numerous companies, the usage of a unified platform for inter-organizational communication and information sharing is required. To develop an integrative, adaptive and intelligent container booking system, a multi-agent architecture is designed in the fourth stage. The proposed architecture will aid the maritime industry in establishing real-time information interchange between autonomous agents, shippers, freight forwarders, and shipping lines. The process outlined in this thesis reveals how the agents communicate with one another to resolve underlying inconsistencies. With the multi-agent framework, the thesis presents a container slot optimization problem considering market segmentation, different booking periods, heterogeneous containers and port congestion scenarios. Using this model the managers can find the booking limit for each type of containers and accordingly they can accept or reject the incoming booking requests.

In a nutshell, this research mainly focuses on developing different decision support models that lead to an efficient and cost-effective freight transportation system.

**Keywords**: sustainable shipping, vehicle speed optimization, maritime shipping, bunker fuel, freight revenue management, container booking system.