A mathematical model for synchromodal transportation in the Seine axis

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1 Synchromodal Transportation

Freight transport volume across the seaports and the hinterland corridors is expected to grow in the coming years due to increased international trade. One of the promising methods to meet the increased transportation demand in the hinterland corridors is by utilizing synchromodal transportation. Synchromodal transportation can be considered an evolution of intermodal transportation with added flexibility and robustness. It is defined as a freight transport framework for the shipment of containers from an origin to a destination using multiple modes of transport while taking into account real-time information about the transportation networks and customer requests for re-planning the itinerary in case of unforeseen disruptions.

Synchromodal transportation is considered as the future of intermodal transportation since both transportation methods are based on the use of multiple modes of transport to complete a shipment. However, the use of real-time data and decision differentiates synchromodal transportation from intermodal transportation[1]. The shippers who have access to this data can optimize the transportation plan in real-time, which is beneficial during uncertain scenarios such as disruptions or blockages. Further, the synchromodality also offers the shippers the possibility to choose an itinerary based on various factors such as total duration, total monetary cost, etc. In this manner, the synchromodality offers flexibility and robustness, which is often lacking in intermodal transportation.

In this study, we are considering the implementation of synchromodality in the Seine axis under the project Flusynchro. The seine axis is a hinterland transportation corridor along the Seine river in France. The Flusynchro project is a real-life case study, the first of its kind in France, intended to promote the growth of a synchromodal logistics platform to enable a modal shift from truck transport to river, rail and short-sea shipping. The modal shift is considered a method to promote sustainable economic development by reducing the emission of greenhouse gases and decarbonizing the shipping industry. While most of the existing literature focuses on reducing monetary expenses such as fees for transportation, storage, and delays, our study additionally considers the total duration of the travel and the emissions produced during transportation. Another distinctive aspect is the calculation of the carbon emission based on the weight of the freight, the distance it travels, and the carbon emissions specific to the mode of transportation. This activity-based function ensures that the emissions accurately reflect real-world conditions. The following section provides a mathematical model description of the synchromodal network problem.

2 Mathematical Model

The input of the synchromodal network problem is a set of available services, S, and a set of requests, R, which are defined as following:

- *Service*: A service $s \in S$ is a transportation using a vehicle, belonging to any mode of transport, between any two terminals i and j, without intermediate stops in between, where $i, j \in N$. Each service will have its own monetary cost and CO2 emission factor per container as well as an available capacity and time schedule.

- *Request*: A request $r \in R$ is defined as a transportation request from an origin terminal to a destination terminal with a fixed number of containers to be transported along with their respective weights(in kg.).

The synchromodal network is modelled as a graph $G = (N, S)$ where N represents a set of terminals(i.e. vertices) and S represents a set of transportation services(i.e. edges). In the model, three modes of transport are considered: Barge, Train and Truck. The barge and rail services are defined with fixed schedules and their capacities are limited. However, the truck services have flexible departures and arrivals and hence the availability of the trucks is always considered with an unlimited fleet size.

The output of the synchromodal network planning problem is a feasible logistic path between the origin and destination terminals of each request $r \in R$, by choosing the best combination of the available transportation services possible while minimizing three objective functions: total transportation cost, total duration of travel and total CO2 emissions. The model also takes into account the capacity limitations for the services and makes sure the capacity of the service is not exceeded while assigning a shipment order. Along with capacity, the time window constraints are considered in the model. These constraints include the release time and due delivery time of a request which are respected while assigning the transportation services. Similarly, for each services the starting time window will be respected and the time integrity is considered if more than one service is used in the shipment of a request. Additionally, transshipment time while switching between two services as well as storage and waiting times at terminals are also taken into consideration in the model.

3 Conclusion and Future work

Small instances for synchromodal transportation network planning for the seine axis river and seaport in France are being generated and will be solved using IBM-Cplex solver to validate our model. Since the problem is NP-Hard, we develop a heuristic approach to solve large instances of the problem. In the literature, synchromodal network planning with uncertain parameters is under-researched [2]. Most of the studies which deal with uncertainties are based on the time-dependent model in which the travel time can be uncertain, particularly for the trucks. However, the transhipment time between the modes is often considered a fixed value. A possible path extension of our model is to consider uncertain transhipment times. In such scenarios where transhipment and waiting time is large, the mathematical model could be able to find an alternative transportation mode or service which is the crux of synchromodal transportation

References

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