Service network design and pricing for intermodal freight transport

Christine Tawfik
University of Liege (ULg), HEC Management School, QuantOM
e-mail : christine.tawfik@ulg.ac.be

Sabine Limbourg
University of Liege (ULg), HEC Management School, QuantOM
e-mail : sabine.limbourg@ulg.ac.be

Intermodal freight transport has recently acquired a rightful position as an ecological choice and provided significant opportunities to generate economies of scale. Nevertheless, both the quality of its services and their corresponding prices have so far failed to attract the desired customer levels ; a concern supported by the recent EU modal split figures. This obviously affects the critical market position of intermodal transport and, consequently, the target EU policies of modal shift in its favor.

In this paper, we consider the problem of simultaneously selecting the intermodal freight services to operate during a certain planning period and determining their associated tariffs perceived by the clients. To our knowledge, joint pricing and service network design problems are intrinsically poorly investigated in the literature, much less in the domain of intermodal transport. The decisions are tackled from the perspective of a typical intermodal operator ; a service provider operating on a rail-inland waterways (IWWs)-road network. The problem belongs to the tactical decision horizon, regarding the underlying network infrastructure as fixed. Furthermore, a simple case of a monopoly is assumed as well as no price or service change reactions from the only competitors : trucking companies. A key design question in this problem is indeed to model the demand volumes of the services in question. For this specific issue, the bilevel progamming framework is decided upon ; a concept scarcely utilized in intermodal transport-related topics, though powerful in hierarchical and non-cooperative decision schemes. On the higher level, an intermodal operator seeks to maximize his profit through service design and pricing decisions, while on the lower level, the target customers seek to maximize their utility through service choice decisions between the offered intermodal and the already existing trucking services.

In order to steadily approach the problem, we start by modeling the higher level as a static service network design problem, while fixing the demand levels and, consequently, omitting the pricing decisions at this stage. The presented problem involves two types of decisions : the frequencies of the services to be offered and the routing of the demands, expressed as itineraries, throughout the service network. A mixed integer mathematical program is considered for that purpose in the interest of operating costs' minimization ; a reasonable primary

objective for both freight carriers and clients.

In the previous sense, two path-based formulations are examined. One is traditionally concerned with domestic, short distance corridors, while the other extends its scope to incorporate basic service performance measures that can potentially become more pronounced on long-distance corridors. In the first formulation, each service is characterized by its origin, destination, transport mode, capacity and its physical route in the network that is, in a first step, simplified to a direct link. A demand's itinerary, on the other hand, corresponds to the sequence of services used to move the flow of the demand in the network. A procedure is implemented at a pre-processing stage to generate geographically feasible itineraries and eliminate those that do not conform to intermodal specific paths' standards. A multicommodity case is studied, where each commodity is defined by its origin, destination and total demand volume. The problem explicitly considers the service frequency and demand itineraries variables that minimize the cost of operating the services and moving the demand volumes over the itineraries, such that the demands' satisfaction and service capacity constraints are respected.

In the second formulation, on the other hand, the tradeoff between the economic and the service performance objectives is particularly addressed. A service is further defined by a service departure day of the week, limiting the frequency of the long haul services to one service per day. For each commodity, an average service duration to deliver the total demand is computed, so that an approximation of the actual exceeded service duration is penalized in the objective function, alongside the costs minimization. The rest of the previous formulation is carried on, with the exception of the addition of necessary constraints for calculating the service duration differences. Furthermore, since long corridors are specially targeted with this problem, round trips of long haul services are ensured through special constraints; a criteria whose presence has been frequently noted in the industry as essential in offering long distance freight services.

Both formulations are tested using a commercial solver. For the first model, the case of Belgium is considered, based on recent figures of yearly transported freight demands and intermodal terminals' locations. For the second model, however, fictitious demands' data are used inspired by actual European freight corridors. Computational experiments of both cases demonstrate a reasonable behavior of the models. The results of the second case, in specific, highlight the tradeoff between the conflicting objectives at the expense of the service network density and accentuate the importance of an accurate penalty parameters' tuning.

In the next stage to proceed with the target bilevel formulation and in order to increase the realism of the model, a survey will be launched among prospective intermodal clients to conclude about their choice criteria of freight services. The drawn results will be further embedded into an appropriate choice model, potentially combined with some probabilistic choice element and ultimately constituting the basis of the lower-level problem.

The underlying research in this work is conducted in accordance with the project BRAIN-TRAINS, concerned with the future of rail freight intermodality in Belgium and Europe, and funded by the Federal Science Policy according to the contract n. BR/132/A4/BRAIN-TRAINS.