A bilevel design and pricing model for an intermodal service network

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In recent years, intermodal freight transport has claimed a rightful position among policy makers and researchers as a sustainable and ecological alternative. Furthermore, when broadly adopted, it provides significant opportunities to generate economies of scale. These two previous reasons have hitherto fueled a wide interest, manifested in governmental incentives and target policies, to stimulate the position of intermodal transport in the EU market. 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.

In this work, we consider the problem of simultaneously designing the intermodal services to operate during a medium-term planning horizon and determining their associated tariffs as perceived by the shipper firms. The decisions are tackled from the perspective of a single intermodal operator/service provider, while accounting for the shippers' choices and assuming no service nor price change reaction from the competition, represented in all-road services, during the process. In more formal terms, a bilevel program is defined as to depict the hierarchical case of decision making, akin to the concept of a sequential Stackelberg game in the field of game theory. To the extent of our knowledge, joint service network design and pricing problems are noticeably under investigated in the literature, much less in the domain of intermodal transport. Moreover, the bilevel programming framework, though proven adequate in similar hierarchical and non-cooperative decision schemes, is still a scarcely utilized concept in intermodal transport planning issues.

Throughout this paper, we essentially provide modeling insights of the bilevel problem in question. More precisely, at the upper level, the intermodal operator (the leader), in the quest of profit maximization, has the precedence of selecting the operating frequencies of their freight services and their corresponding prices. While at the lower level, the shippers (the followers) presented with feasible itineraries as sequences of the leader's services, decide on the volumes of their demands to send over these itineraries and the available trucking alternative. Due to the particular structure of intermodal networks, a path-based formula-

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tion is considered, incorporating three transport modes: road, rail and inland waterways. At a pre-processing stage, a procedure is implemented to generate geographically feasible itineraries and eliminate those that do not conform to intermodal specific paths' standards. Additionally, we shed light on a problematic type of constraints; the service capacity constraints that involve variables from both the upper and the lower level, an issue particularly highlighted in previously related works [1, 2]. We discuss different alternatives for their position at the upper or the lower level, formulation and the implications of each on the problem's complexity and solutions.

In order to increase the realism of our study, the lower level problem is expressed based on an idea to combine discrete choice methods with the minimization of total logistics costs; a perspective defended in [3] as analogous to utility maximization modeling in passenger traffic. Normative approaches provided by traditional cost models repetitively fall short of coinciding with the shippers' actual choices, principally due to the lack of significant information and the nonuniform shippers' perception of the service quality. We propose a statistical approach to estimate the missing information and the importance of the cost components. We consider elements that embody the shippers' actual expenses and interpretation of the level of service. The analysis is to be based on revealed preference data, elicited through a survey among prospective intermodal clients. We believe this would be the first time to integrate a choice model in the reaction of the followers in bilevel pricing and design models.

In the next stages, we intend to conduct computational experiments for a proof of concepts, using reasonably designed instances. The innate complexity of bilevel programs already suggests the need to devise solution and decomposition algorithms that exploit the particular problem's structure, in order to be able to invoke it on large and real-life inputs.

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