Models and Algorithms for Solving the Multi-criteria Itinerary Planning Problem on International Multimodal Transportation Networks

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Planning an international journey involves the determination and assessment of alternative itineraries emerging from combining various international, interurban and urban transport services. Apart from the inherent difficulties of journey planning, the execution of any travel plan is associated with substantial risk due to the dynamic characteristics of the underlying transportation network. Thus, the development of itineraries for international multimodal trips and the dynamic replanning of these itineraries constitute a major requirement in the travellers' community. In response to this need various journey planning systems have been developed aiming to provide the traveler with journey planning services throughout the entire journey lifecycle (Zografos et al., 2010; Peng and Huang, 2000; Horn, 2004). However, the emerging journey planners involve mathematical models and optimization algorithms dealing with urban and or interurban trips. Moreover, the itinerary planning problem addressed by the existing journey planners deals either with a single criterion or multiple criteria treated through a single objective function or lexicographically. On the other hand, the real time on-trip information services provided by the currently available systems is basically focused on sending alerts without offering any dynamic re-planning capabilities (Zografos et al., 2010). This paper is focused on presenting, modeling, and solving the relevant static and dynamic itinerary planning problems defined on an international multimodal transportation network taking into account network and schedule based constraints expressing travelers' requirements and priorities. The criteria under consideration include travel time, CO2 emissions, cost, and number of transfers. Special emphasis is placed on addressing issues arising from modeling the underlying international multimodal transportation network.

The static international itinerary planning problem is defined on a multimodal transportation network involving international, interurban and urban transport modes covering a wide geographical area. In particular, the international itinerary planning problem is associated to an international transportation network which consist of the following elements:

- The origin and final destination of the trip
- The International gateways (i.e. terminal stations having at least one international connection) associated to the final destination.
- The international gateways associated to the origin of the trip.

- The transportation links that connect the international gateways and the transportation links that connect the origin and the destination of the trip with the associated international gateways.

Before the solution of the itinerary planning problem the associated underlying network is customized to reflect the transport services which are applicable for the specific origin-destination pair. The solution of the multi-criteria multimodal international itinerary planning problem is performed in two stages:

- In stage I, the international part of the trip is identified, (i.e., sequence of international segments from the origin to the destination), including the interurban transfer from the origin to the first international gateway and the interurban transfer from the last international gateway to the destination by using only a rough travel time estimate.
- In stage II, each of the identified generic itineraries is further refined by identifying the urban and interurban sub-itineraries.

The dynamic itinerary planning problem emerges when upon the arrival of a traveler heading towards an intermediate stop of his/her journey, a subsequent scheduled transport service becomes disrupted. The objective of the arising problem is to redefine an itinerary that may take him/her to the destination within a desired arrival time window. The features that fully define the problem are the following: i) existence of subsequent mandatory or booked services (which must be used or using them saves some penalty), ii) the node from which the journey may be continued, and iii) the type of disruption. The criteria used for this problem are similar to those used for the static problem however a lexicographical ordering is used in order to determine: i) the cheapest alternative, ii) the alternative that deviates the minimum from the initial time constraints (i.e. arrival time at the destination), iii) the shortest alternative, and iv) the alternative (if one exists) that uses the same international services with the initial one.

Both the static and the dynamic international itinerary planning problems are formulated as multi-criteria time-constrained path finding problems. Label setting algorithms are proposed for the solution of both problems (Hamacher et al., 2006).

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