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Integrating uncertain travel times in the Service Network Scheduling Problem with Hub Processing Capacities

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Problem description. We consider a parcel transportation network planning problem in the context of the activities of a carrier for e-commerce suppliers. The carrier network is composed of suppliers, hubs and terminals. Packages are picked-up at suppliers, sorted and transferred at hubs in order to be routed to their destination terminals, from where they are dispatched in local delivery routes. The planning is built on a rolling horizon of several days. The transportation demand in the network is modeled as commodities, each having an origin, a destination, a release date at its origin and a due date at its destination. In addition to this data, a commodity is considered to always follow the same path in the network, decided beforehand at a strategic level. Each arc on the network is associated with a cost for one truck move on the arc. The problem consists of planning truck moves in the network, deciding the departure time of each truck and the dispatch of commodities among trucks such that the demand is satisfied. The objective is to minimize the sum of transportation costs. This problem is called Service Network Scheduling Problem (SNSP, [2]), which falls in the scope of Service Network Design Problems, recently reviewed in [1].

Since delays in such networks generate late deliveries and low service quality [3], we focus in particular on the impact of travel time uncertainty on the performance of the network. This is exacerbated in our case by the fact that a planned vehicle always leaves at the scheduled time, hence missed connections due to late arrivals at a hub are typically rescheduled to the next truck. Furthermore, processing capacities at hubs are limited. As a result, a delay may also generate congestion at a hub, increasing sorting times and inducing more cost or in-time delivery failures. To our knowledge, the connection between travel time uncertainty and hub processing capacities has not yet been studied in the literature.

The first goal of our study is thus to evaluate the impact of limited processing capacities at hubs on the network cost and service level. In addition, we evaluate the effectiveness of including the stochasticity of travel times in the mathematical formulation and assess its impact on the final solutions obtained.

Methodology and experiments. We model the SNSP with travel time uncertainty and Hub Processing Capacities as a two-stage stochastic program. The originality of our formulation is the duplication of hubs where sorting operations occur and the introduction of space-time sorting arcs between hubs’ entry and exit with a limited processing capacity.

Preliminary results. We apply our model on a small instance built from real data provided by an industrial partner. The network is composed of 9 hubs among which 1 central hub where sorting operations occur. We consider a time horizon of two days with a granularity of half an hour. In total, several thousands of parcels are split into dozens of commodities by origin, destination, release date and due date. We investigate the connection between the travel time uncertainty range and the central hub processing capacity in Table 1, using 10 scenarios per uncertainty range. Our results show that more uncertain scenarios lead to more infeasibility from solutions obtained with optimistic and median travel times. A faster processing capacity allows to solve more scenarios. Solutions obtained using pessimistic travel times estimation are always feasible but at a higher average cost, while our stochastic program produces solutions that remain feasible in any scenario at reasonable costs. Future research directions include solving larger instances and using chance constraints to model service levels.

Processing capacity	Uncertainty range	Travel times									Stochastic programming		
		optimistic			median			pessimistic			# solved scenarios	cost ratio	
		# solved scenarios	cost ratio		# solved scenarios	cost ratio		# solved scenarios	cost ratio			avg.	max.
			avg.	max.		avg.	max.		avg.	max.			
reference	reference	10/10	2.09	9.24	9/10	0.54	1.21	10/10	2.41	3.36	10/10	0.5	1.21
	higher uncertainty	8/10	0.73	1.07	9/10	0.79	1.16	10/10	2.71	3	10/10	0.77	1.07
+10% processing capacity	reference	10/10	1.99	5.55	10/10	1.23	3.5	10/10	2.4	3.27	10/10	0.5	1.21
	higher uncertainty	10/10	2.49	9.74	9/10	0.76	1.03	10/10	2.68	2.92	10/10	0.77	1.07

Table 1: Delay costs over transport costs ratios.

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