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BUS NETWORK DESIGN WITH ELASTIC DEMAND

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Summary: This work applies a mixed-integer linear programming formulation to optimize a small bus network design and frequency setting problem with elastic demand, in Portugal. The formulation integrates discrete choice models in a linear optimization model at the cost of discretizing the routes' frequencies. A small number of possible frequencies were chosen, aiming to represent different levels of service. Typical implementations use non-linear heuristic methods, bi-level optimization or other iterative algorithms which do not ensure convergence to the optimal solution. By using a mixed-integer linear programming formulation, the optimal solution is obtained, or at least a given optimality gap is observed (i.e. an upper bound on the distance between the solution and the optimal one).

The current bus stops in the area under study were grouped into nodes of the most relevant locations for the network. The current bus routes were expressed with those nodes, and new routes were suggested using expert knowledge. Travellers' references were taken into account by considering different possible modes of transport for each origin-destination pair and quantitatively evaluating how those other options compare to the bus network. Each possible itinerary within the network was pre-computed and compared against each of the best itineraries of the competing modes of transport, which were obtained using Google Maps. Each itinerary in the network got assigned its probability of being chosen based on its utility, using a multinomial logit model which takes into consideration its access, waiting and travel time, cost and number of transfers. The solver aims to maximize the total network demand by tuning its active routes and frequencies, activating the itineraries with the highest probability of being chosen, allocating most or a pre-determined percentage of the demand to them, constrained by the capacities and number of buses. The demand for each origin-destination pair is estimated assuming all travellers travel in the highest utility active itinerary.

Different modelling perspectives can be included, other than maximizing the total network demand, since the formulation is compatible with a wide variety of objective functions such as equity of access to the network over all origin-destination pairs. The formulation developed can be used by network planners to simulate how travellers would respond to proposed network changes; by bus operator companies to adjust their network to the expected demand and to simulate the impact that different social policies, such as minimum network coverage or minimum levels of service on certain areas, would have on the total network ridership and coverage.