Enhancing urban mobility:
Integrating ride-sharing and public transit

Introduction of the case study:-

Seamless integration of ride-sharing and public transit may offer fast, reliable, and affordable transfer to and from stations in urban areas thereby easing and enhancing mobility of people. The potential benefits of such a system is to have cheaper and more environmentally sustainable alternative is to use existing private car trips as a feeder for public transit. Ride-sharing and public transit can, in fact, complement each other. On the one hand, ride-sharing can serve as a feeder system that connects less densely populated areas to public transit. On the other hand, the public transit system can extend the reach of ride-sharing and reduce the alone time of the drivers.
Our goal is to achieve the optimal solution for the models we are implementing and to show the integration of a ride-sharing system and a public transit system can significantly ease and enhance mobility, and increase the use of public transport and how the different types of ride matching problem needs to be handled differently according to the constraints, they subjected to.

Types of Ride Matching:

- A ride-share match: a match between a rider and a driver in which the driver transports the rider from his origin to his destination.

- A transit match: a match between a rider and a driver in which the driver transports the rider to a transit station. Subsequently, the driver drives to his destination while the rider takes public transit to reach his final destination.

- A park-and-ride match: a transit match in which the driver parks his car and then uses public transport to reach his final destination.

A ride-share match always involves one rider, but both a transit match and a park-and-ride match can involve one or two riders. At this stage, we do not consider matches with more than two rider pickups. The main reason is that it would increase the inconvenience for the driver (it will increase the driver's journey time and it will increase the risk of delays on the driver's journey).

Approach:

Our ride-matching algorithm consists of a match identification phase in which we will find all feasible driver-rider matches and an optimization phase in which the optimal matching between driver and rider is determined (based on the set of feasible matches). Match identification is performed separately for each match type, i.e.,

- ride-share matches, - which is a relatively simple task as it just requires a straightforward iteration of all possible driver-rider pairs based on several constraints,
- transit matches, and park-and-ride transit matches - in which identification of feasible matches requires several preprocessing procedures.

To identify feasible matches with two riders, we take advantage of the property that a match between driver i and riders j and k, (j!=k), can be time feasible (but not necessarily) only if the matches between driver i and rider j and driver i and rider k are both time feasible.

To find the optimal driver-rider pair, construct a bipartite graph with weights being the number of riders in the match, and the additional driving distance for drivers, which is then used to optimize our objective function.

3.1. Assessing the feasibility of a ride-share match

A ride-share match involves a driver $i \in D$ and a rider $j \in R$. The departure time e_i^j of a driver i matched with rider j depends on the announcement submission time of rider j, the earliest departure time of rider j, and the trip duration from o_i to o_j and is set as follows $e_i^j = \max(e_i, \sigma_j, e_j - t_{o_i o_j})$. This assures that driver i does not wait for rider j at o_j. The pickup time, e_j^i, of rider j is $e_i^j + t_{o_i o_j}$ and the arrival time, l_j^i, at the rider's destination is $e_j^i + \tau + t_{o_j d_j}$. Driver i will arrive at his destination at time $l_i^j = l_j^i + t_{d_j d_i}$. The ride-share match is feasible only if the trip time duration for driver i, i.e., $l_i^j - e_i^j$, is less than or equal to T_i. Also, driver i and rider j must arrive at their destinations before their latest arrival times l_i and l_j, respectively.

Let E represent the set of all edges in the bipartite graph and let the binary decision variable x_e for edge $e \in E$ indicate whether the edge is in an optimal matching ($x_e = 1$) or not ($x_e = 0$). Furthermore, let E_i and E_j represent the set of edges in E associated with driver i and rider j, respectively. Then, our ride-share matching problem with the objective of maximizing the number of matched riders can be formulated as the following integer program:

$$\max z_1 = \sum_{e \in E} v_e x_e$$

$$\min z_2 = \sum_{e \in E} \delta_e x_e.$$

subject to

$$\sum_{e \in E_i} x_e \leq 1 \quad \forall i \in D,$$

plus the additional constraint $\sum_{e \in E} v_e x_e \geq z_1^*$.

(z^*_1 is maximum value of z_1)

$$\sum_{e \in E_j} x_e \leq 1 \quad \forall j \in R,$$

$$x_e \in \{0, 1\} \quad \forall e \in E.$$

References:

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