Share a ride to the train station using a demand-responsive feeder service

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Demand Responsive Transit (DRT) is a form of flexible public transportation in which the routes and schedules are determined per ride, based on the needs of passengers. Different forms of the DRT concept have been implemented throughout the last few decades. Nevertheless, modern technology is gradually making it a more viable solution by easily allowing users to input the origin and destination of the trip, and their required departure or arrival time. Using the collected data, the system can coordinate the optimal combination of routes that best satisfies the needs of its users within the given constraints.

Existing DRT services generally operate using mid-size vehicles such as vans or mini-buses. The cost to the passenger is usually somewhat higher than the price of riding a bus, yet aims to be significantly cheaper than a regular taxi, since the rides are shared. The route traveled may deviate from the direct route to some extent in order to accommodate the additional passengers, meaning that it is not as fast as a taxi. Even so, it is meant to be faster and more convenient than riding a bus.

Rail networks provide fast and convenient service that covers long distances, bringing passengers from one point to another efficiently. However, they do not offer a complete solution that includes the first and last mile. Many train stations, located on the outskirts of cities and in rural areas, are not easily accessible by public transport, leading many passengers to prefer traveling to the station using their car. As a result, parking lots at the stations tend to quickly reach their maximum capacity and cannot fully support the demand.

In this research we examine a DRT system that serves as a feeder service for train stations. An optimization model is introduced to evaluate the proposed service's effectiveness and characteristics. The model takes into account various parameters such as expected ridership, the size and capacity of the fleet, required time window for pick-up and the geography of the road network. The objective is to minimize overall travel time of all vehicles providing the service, while simultaneously reducing passenger waiting and travel times. By supplying an alternative to travel by private car and grouping several passengers in one vehicle, there are several added benefits such as reducing fuel consumption, pollution, traffic congestion and parking costs.

Our research is aimed at providing decision-makers with scientific tools that can assist them in assessing the feasibility of establishing a DRT feeder service, determining its characteristics, and selecting the stations at which it would be advisable to implement such a solution. Once such a service is established and has proved itself, it can be expanded to include additional applications with similar features such as educational institutions, industrial parks, and commercial and recreational centers. In the longer term, DRT can also become a standard and widespread method of transportation within a metropolitan area and its surrounding suburbs.

Performing the necessary planning and coordination of a real-time dynamic DRT system is a complex and challenging problem. Implementing a DRT feeder service for train stations has several simplifying factors that decrease the difficulty of identifying a satisfactory solution, and increase the ability to establish a successful service. By definition, the pick-up or drop-off location at one end of the route is shared by all passengers, and, since trains run on a fixed schedule, the required arrival or departure time from the train station is also aligned between the passengers and known in advance. In addition, train users generally aim to board a specific train, and plan their travel arrangements to the station ahead of time. This provides a wider time window for performing the necessary calculations, and for properly coordinating between the passengers and the vehicles.

An optimization model has been implemented using the IBM ILOG CPLEX optimization engine. The model was initially created using a three-index formulation of VRPTW (Vehicle Routing Problem with Time Windows). However, it became apparent that the optimization process was relatively lengthy, especially for scenarios that were more complex. When a more efficient two-index formulation was introduced, the solve time improved substantially.

An automated platform has been developed to enable large-scale experimentation. Numerical experiments were designed using actual survey data collected at train stations. Passengers were divided into groups according to the train schedule, while each instance included the number of requests for service and the location for pick-up. The experiments were carried out using a wide range of scenarios and their results were assembled and analyzed. So far more than 26,000 scenarios have been executed, with a total run time of over 600 hours.

Initial analysis of the numerical experiments has demonstrated that the size of the time window for pick-up (the amount of time beyond the direct travel time to the station that may be added to a passenger's journey to enable pick-up of additional passengers along the route or near it) has a significant impact on the overall travel time and operating cost. The most significant improvement occurred when expanding the time window from five minutes to nine or ten minutes.

Next steps include in-depth analysis of experiment results and executing drill-down experiments as necessary. The model will be enhanced to handle scenarios that are more complex, and approximation methods will be utilized for cases that cannot be solved optimally in reasonable time. We will expand the model to evaluate the potential economic and environmental benefits of the DRT service and for making decisions regarding the locations and characteristics of a pilot program.

We hope that the platform we have developed, combined with the experiments and analyses that have been performed so far, will be our modest contribution to encouraging more efficient and convenient public transportation methods, and providing stakeholders with tools that will assist them in the decision-making process regarding these types of services.