DRISI
Caltrans Division of Research, Innovation and System Information

Research Results

Coordinating Transit Transfers in Real Time

This research develops control strategies based on real time information to reduce transfer delay.

Modal

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Project Title:
Coordinating Transit Transfers in Real Time

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WHAT IS THE NEED?

Public transit networks usually resemble one of several common patterns including ringradial, grid, hierarchical (e.g. feeder-trunk), etc. These designs are closely tied to the historical development of cities and to the layout of the street network. They also tend to be efficient methods for achieving spatial coverage. Transfers are essential for reaching destinations in grid and hierarchical systems and increasingly in ring-radial systems too because travel demand has become much more polycentric in recent years. Transfers take on particular importance in California because the metropolitan areas tend to have a large spatial extent and moderate density. The density is sufficient to support good transit coverage, but in most cases is not enough for high frequency service. As a result, accessing destinations by transit in California metro areas often involves long distances, one or more transfers, and a huge penalty for missing a transfer. These conditions discourage people from riding transit. Transfer waiting time and, by extension, travel time reliability could be greatly improved with real-time coordination.

WHAT WAS OUR GOAL?

The research will look for ways of controlling public transportation buses at transfer stations, and at traffic signals while en route, in order to improve the reliability of passenger connections between transit routes.

WHAT DID WE DO?

Transfers are a major source of travel time variability for transit passengers. Coordinating transfers between transit routes in real time can reduce passenger waiting times and travel time variability, but these benefits need to be contrasted with the delays to on-board and downstream passengers, as well as the potential for bus bunching created by holding buses for transfers.

We developed a dynamic holding strategy for transfer coordination based on control theory. Our approach is distributed, with each bus serving as its own decision maker. Distributed control has the advantage of being scalable to large networks. The strategy works as follows: When a bus arrives at a transfer point, it collects information on upcoming bus arrivals, counts of through and transferring passengers, and the uncertainty in these estimates. These values are used to calculate the bus's maximum holding time. If a connecting bus is expected before the maximum hold time, the deciding bus holds for a coordinated transfer. Otherwise, it departs immediately.

Control formulations are developed that use this decision rule with deterministic and uncertain information. The objective function for both is the expectation of net transfer delay, which includes the delay experienced by onboard passengers when transfer coordination is applied and the time that transferring passengers wait when there is no coordination. We obtained the optimal control strategies for deterministic and uncertain information by finding the expression for maximum holding time that minimizes the objective.

We simulated a wide range of values for all parameters and found that the net transfer delay with control is never worse than no control and can be significantly reduced when there are many transferring passengers. The time savings from transfer coordination increase with the ratio of transferring to through passengers but diminish as uncertainty in the real-time estimates of bus arrivals increases. We also found that the difference between the deterministic and uncertainty formulations is relatively small, except when there are very few transferring passengers. This finding implies that the deterministic control could be used in place of the uncertainty control without much loss of performance. This approximation might be desirable because the deterministic control is easier to implement and avoids an assumption about the accuracy of bus arrival estimates that is required for the uncertainty control.

WHAT WAS THE OUTCOME?

We then tested the proposed control on a case study with real data. Field observations at a multimodal transfer point (Rockridge BART station) in Oakland collected real and estimated arrivals, passenger flows, and passenger walking times. We applied the proposed control strategy on this data and found a reduction in net transfer delay by 30-39% in this real-world scenario. The reduction is given as a range instead of a single value because it depends on how long it takes the bus to recover the holding time and get back on schedule.

There are several complementary measures that could allow transfer coordination to be applied in more cases. Providing better real-time and wayfinding information at major transfer points could reduce walking time as passengers quicken their pace to make a transfer or spend less time figuring out where to go. A smartphone app which allows passengers to communicate their travel plans to the transit agency could provide a realtime estimate of transferring passengers.

WHAT IS THE BENEFIT?

The benefit of the research is to improve bus operations by making transfers shorter and more reliable. This would make bus transit more attractive, potentially reducing automobile usage and greenhouse gas emissions.

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