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An Intermodal Dynamic Traffic Assignment Framework for Integrated Corridor Management Applications

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Abstract

Integrated Corridor Management (ICM) is generally defined as the use of advanced traffic management technologies to coordinate the operation of adjacent highway facilities and transit services in order to improve travel efficiency, reliability and safety along congested urban corridors. The goal is to promote multimodal operation that allows travelers' shift across the different mode networks to efficiently manage recurrent and non-recurrent traffic congestion through maximizing the use of these networks' spare capacities This paper describes a multimodal dynamic trip assignment-simulation modeling framework that can be used to evaluate the effectiveness of ICM strategies. The framework considers different travel modes such as private cars, buses, and metro/subway. It captures the interaction between mode choice and traffic assignment under different information provision and network control scenarios. A description of the different components of the model is given in this paper.

Keywords: Dynamic Traffic Assignment, Intermodal Networks, Integrated Corridor Management.

An Intermodal Dynamic Traffic Assignment Framework for Integrated Corridor Management Applications

Background

Large metropolitan areas are typically characterized by one or more congested corridors that serve a considerable portion of the daily commute trips. These corridors usually include various adjacent highway and transit networks (e.g., freeways, toll roads, managed lanes, surface arterials, bus services and light/heavy rail) that provide similar or complementary transportation functions. They might also include cross-network connections (e.g., transit centers and park-and-ride facilities) that allow the individual networks to be readily accessible from each other. Integrated Corridor Management (ICM) is generally defined as the use of advanced traffic management technologies to coordinate the operation of adjacent highway facilities and transit services in order to improve travel efficiency, reliability and safety along congested urban corridors. The goal is to promote multimodal operation that allows travelers' shift across the different mode networks to efficiently manage recurrent and non-recurrent traffic congestion through maximizing the use of these networks' spare capacities.

Advanced Traffic Management Systems (ATMS) for ICM incorporate a wide range of traveler information and traffic control strategies. For instance, they include strategies related to providing travelers with pre-trip and en-route information on expected travel times along the different highway and transit facilities, alternative route and travel mode options, and parking availability information. Furthermore, they integrate control strategies for freeway management (e.g., ramp metering, lane management, DMS en-route information, etc), arterial management (e.g., adaptive signal control, path-based signal coordination, reversible lanes operation, etc) and transit management (e.g., transit vehicle preemption, real-time dispatching, etc) to maximize efficiency benefits associated with adopting these strategies. They also adopt congestion pricing and other demand management strategies to reduce congestion intensity during peak periods. Evaluating the effectiveness of these strategies requires advanced modeling capabilities that capture explicitly the dynamic interactions between mode choice and traffic assignment. They should also capture the resulting traffic evolution along the different highway and transit facilities as function of travelers' responses to the adopted information and control strategies.

This paper describes a multimodal dynamic trip assignment-simulation modeling framework that can be used to evaluate the effectiveness of ICM strategies. The framework considers different travel modes such as private cars, buses, and metro/subway. It captures the interaction between mode choice and traffic assignment under different information provision and network control scenarios. It implements a multi-objective assignment procedure in which travelers choose their modes and routes based on a range of evaluation criteria. The model assumes diverse set of travelers in terms of their relevant choice criteria and access and response to the supplied information. The framework is used to model the US 75 corridor in Dallas, Texas. The corridor extends over five cities in the Dallas metroplex. It consists of 272 lanes-miles of freeways and frontage roads, 167 centerline miles of arterial streets with about 900 signalized intersections, 105 lane-miles of tollways, two light rail lines with 20 stations and nine park-and-ride facilities and 79 bus routes. Figure 1 illustrates the corridor travelshed area that is considered in this study.

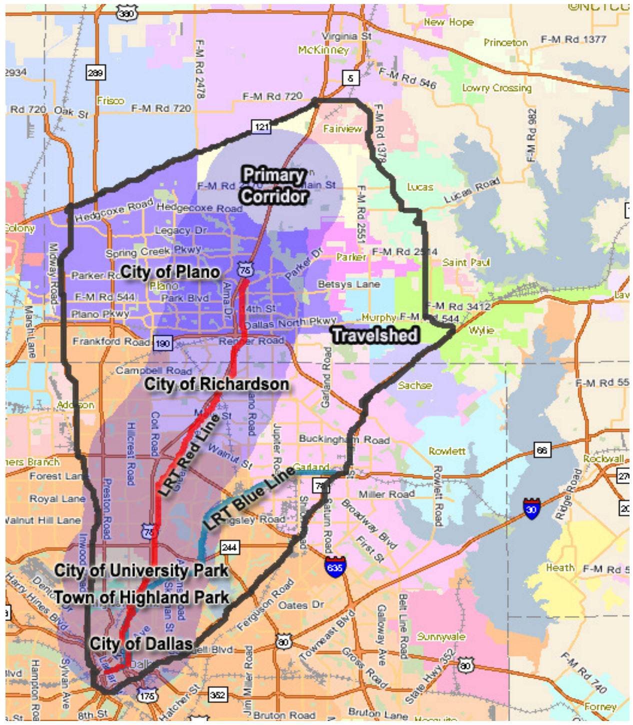

Figure 1: The Travelshed Area of the US 75 Corridor

Modeling Framework

The overall modeling framework is illustrated in Figure 2. The model generates travelers on the basis of pre-specified time-dependent Origin-Destination (OD) zonal demands. Each generated traveler is then assigned a set of attributes, which include his/her trip starting time, generation link, final destination and a distinct identification number. Each traveler is also assigned a list of attributes to describe her/his preferences in choosing her/his best travel option. These attributes are randomly generated from distributions representing the travelers' population preferences for the traveler's origin zone. The model allows representation of complete transit networks, with both exclusive and shared infrastructure. A set of bus lines is defined in terms of the constituent routes, for which the average headway, stop locations, and vehicle capacities are specified. Different bus capacities may be specified for the different routes. Given a timetable, buses are generated from their origin terminals and moved in the network along their pre-specified routes following prevailing traffic conditions. The model tracks all buses along their routes and records their respective arrival times at each stop. The model is also capable of simulating special bus services such as express service with limited stops and bus services with different deadheading strategies in which some stops could be skipped under certain conditions. Prevailing travel times on each link are estimated using a vehicle simulation component, which moves vehicles capturing the interaction between autos and transit vehicles. If separate transit lanes exist, transit vehicles move on these exclusive lanes according to their prevailing speeds with no interaction with the automobile traffic.

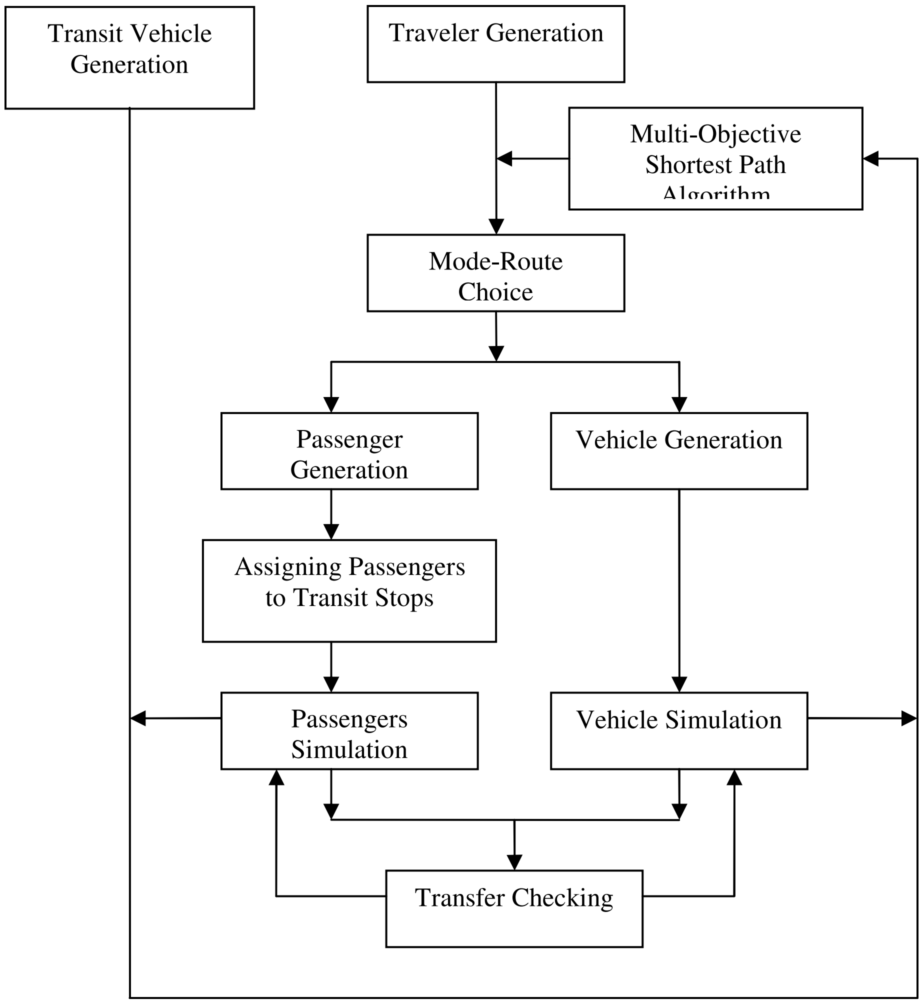

Figure 2: Overall Modeling Framework

A mode-route decision module is activated at fixed intervals to provide travelers with a superior set of mode-route options. These superior paths are computed in terms of a list of attributes such as travel time, travel cost, parking cost, waiting time, parking availability, etc. The activation interval (usually in the range of 3 to 5 minutes) is set such that the variation in network conditions is captured, while retaining desirable computational performance for the procedure. The route-mode decision module consists of a multi-objective shortest path algorithm designed for large-scale intermodal transportation networks. The implemented algorithm defines the intermodal transportation network as a set of layers, with each layer representing the sub-network of a certain mode. It determines the non-dominated paths from all nodes in the network to all destinations. The logic of the implemented algorithm is based on the “divide and conquer” technique in which the non-dominated sub-paths between every two transfer nodes in the network are first determined. The search in this step includes all modes' subnetworks (layers) connecting these two transfer nodes. These non-dominated sub-paths are then composed together to generate the non-dominated (single mode and intermodal) paths between the origin and the final destination.

The model framework allows implementation of different mode-route choice models that might adequately represent the travelers' behavior. The implemented model could be deterministic or stochastic and could be based on compensatory or non-compensatory choice rules. Deterministic models typically assume availability of perfect information for travelers and that travelers choose the best alternative based on the available information. Stochastic models (e.g. logit form or probit form), on the other hand, take into consideration that information might not be perfect and that travelers may have different perception of the supplied information. In the current implementation, the model assumes a stochastically diverse set of travelers with different relevant choice criteria and response mechanisms to externally supplied information (if any). Based on the available options and the traveler's preference, a traveler may choose a "pure" mode or a combination of modes to reach his/her final destination. If a traveler chooses private car for the whole trip or part of it, a car is generated and moved into the network with a starting time equals to its driver starting time. Each newly generated vehicle is assigned an ID number that is unique to this vehicle. Vehicles are then moved in the network subject to the prevailing traffic conditions until they reach the location of their final destination or the next transfer node along the pre-specified route (in the case of an intermodal trip).

If a traveler chooses a transit mode, he/she is assigned to a transit line such that the destination of this passenger is a node along the route followed by the bus line. If no single line is found or if the passenger is not satisfied with the available single line, the passenger is assigned to a path composed of two lines with one transfer node, such that the destination of the passenger is a node along the route followed by the second bus. Given the passenger's origin node, the nearest transit stop along the first line in the passenger's path is determined, and he/she waits until the arrival of the next vehicle that serves that transit line.

As mentioned earlier, upon the generation of a traveler, the list of non-dominated travel options between the downstream node of the traveler's generation link and the traveler's final destination is extracted from the shortest path calculation module. This list of non-dominated travel options is independent of the traveler's generation location on her/his generation link. However, to consider the impact of walking distance on travelers' mode-route choice, the walking distance and the associated walking time to the transit stop closest to the traveler's generation location are calculated and added to the corresponding labels of all travel options that start with a transit mode. If a passenger is generated on one of the links of the starting transit line, the closest bus stop to the traveler generation location is determined and the passenger walking distance is calculated as the difference between the traveler generation location and the stop location (both are measured as distance from downstream intersection). If a traveler is generated on one of the inbound links to a link that is served by a transit line, the walking distance is calculated as the sum of the traveler distance to the downstream node of the generation location plus the distance between the upstream node of the next link and first non-skipped stop on the next link. Upon arrival at a bus stop, buses are held to allow passengers to board and alight. The number of passengers on-board is updated, representing the new bus occupancy, which is also tracked along the vehicles' routes. If a vehicle is full, no passengers are allowed to board and all waiting passengers are reassigned to the next bus or to another trip plan. Upon the arrival of a vehicle (private car or transit vehicle) to a certain destination node, this destination is compared to the final destinations of the travelers on board. If it matches the final destination of a traveler, the current time is recorded for this traveler as his/her arrival time. If they are different, the traveler transfers to the next transit line in his/her plan. The nearest stop is again determined and the traveler waits for his/her next transit vehicle. The time difference between arrival at the transfer node and boarding of the next line is calculated as the waiting time at the current transfer node for this traveler.

The model produces detailed output statistics at both the aggregate and the disaggregate levels. For example, it produces various state descriptors of the different elements in the system such as links, lanes, intersections, travelers, private cars, transit vehicles and transit stops. The link's descriptors include travel times, stopped times, speeds, densities, queues, etc. It also produces space and time trajectories of each traveler; the trajectory includes the travel time on each link, the stopped time at each node, and waiting time at bus stops and transfer points. Information on time-space vehicle loading pattern for each transit vehicle could also be generated. The model also produces statistics aggregated over all travelers including the average travel time, travel distance, passengers walking distance, passengers waiting time, etc. Statistics can be obtained for any subset of travelers, classified on any relevant basis, such as travel mode type. A snapshot of the model's graphical interface illustrating a 3D view of the modeled corridor is given in Figure 3.

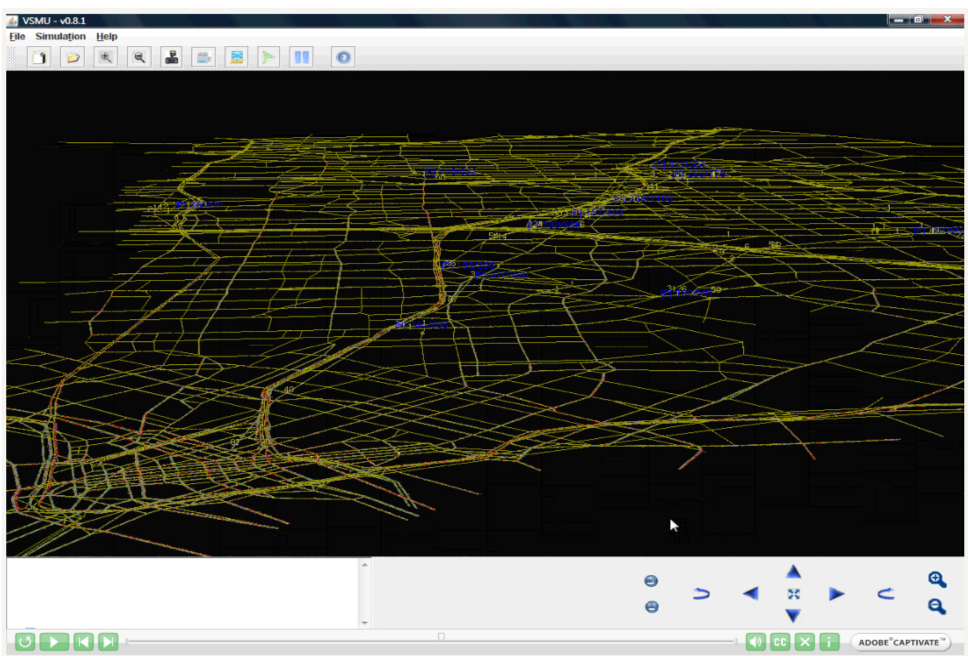

Figure 3: A Snapshot of the Model's Graphical Interface Illustrating 3D View of the Travelshed Area of the US 75 Corridor