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STATE OF PRACTICE: WHITE PAPER ON UNDERSTANDING AND IMPLEMENTING DYNAMIC TRAFFIC ASSIGNMENT FOR PRACTICAL APPLICATIONS

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Increasing congestion and limited financial resources require the use of appropriate tools to evaluate transportation projects that can capture the dynamic and stochastic interactions between demand and supply. Travel demand models have historically been used to size infrastructure and evaluate land use and transportation projects, but when analyzing the increasingly complex transportation issues such as peak spreading, and measuring potential impacts to overly congested areas through operational/capacity improvements, variable pricing/managed lanes, intelligent transportation systems (ITS), and other similar projects, the traditional fourstep travel demand model falls short.

Traditional models do not account for peak spreading since they allow all the trips to arrive at their given location in the modeling period when in reality they would be stuck in a queue or still traveling many miles. For example, a peak hour trip that the model estimates would take three hours would be allowed to be completed in the peak one hour. Travel time in traditional models is only a cost that the assignment tries to minimize, not a constraint to how far the trip can actually go.

Since traditional models do not account for queues and other interactions between vehicles that reduce capacity, operational/capacity improvements such as adding turn-lanes are not captured. Many times the intersection and turning lane capacities are the limiting capacity of the roadway, so not incorporating these delays into the evaluation of the project types mentioned previously might result in unreasonable results.

One method developed to help address these issues is dynamic traffic assignment (DTA). This white paper focuses on three aspects of DTA as they relate to highway assignment:

- **What is Dynamic Traffic Assignment?** – Discuss how DTA differs from previous assignment methods and define a common language for use in discussion of DTA as it relates to transportation demand forecasting as opposed to traffic engineering and traffic operations analysis.
- **Why is Dynamic Traffic Assignment Used?** – Describe the issues with previous assignment methods and how DTA attempts to address these issues.
- **How might Dynamic Traffic Assignment be implemented?** – Summarize discussions with practitioners, software vendors, and case studies/literature review to assess the future of DTA and potential methods for linking transportation demand models and dynamic traffic assignment.

What is Dynamic Traffic Assignment

Unlike static assignment, where the flow along a link and through a junction is allowed to exceed the capacity, the flow in DTA models is metered by the operational capacity of the links and junctions. The packets of vehicles will queue and even block entire links and upstream links. Therefore, the actual congestion is taken into account and travelers find alternate routes to avoid blockages in the system. For example, a static assignment may have a volume exceeding capacity by 5 percent and the result would be reduced speed (i.e. increased travel time) on the segment. The same situation for a DTA would result in a queue the distance of the residual demand or in some cases a diversion of assigned trips to an alternate route.

Another key aspect of DTA models is that they not only account for physical capacity and any resulting delay, they also account for the time aspect of travel. Time is typically taken into account at the departure by specifying some sort of distribution over time using the first-in first-out (FIFO) principle. In this way, trips departing first travel on the network the feasible distance under the speed conditions along the selected route. Depending on the level of congestion, and the area and time period being modeled, it is common for some trips to never reach their destination. These trips either left too late, needed to travel a long way, or congestion did not allow them to progress at a reasonable speed. This is different than typical demand models that allow all trips to reach their destination "instantaneously", occurring on every link along the path simultaneously.

Since the nomenclature used between various software vendors is different, we recommend the following definitions to describe the level of detail for travel demand models:

- **Macroscopic** – Vehicles represented as flow without consideration for size or storage space.
- **Mesoscopic** – Vehicles represented as packets with total space on the link being allocated; no lane changing or interaction between packets other than the amount of space needed for storage.
- **Microscopic** – Vehicles represented as packets with space being allocated for each lane; interaction between packets is represented by lane changing, turning, and blocking. This definition is more consistent with definitions used in traffic engineering and traffic operations and is important for clarifying key differences between mesoscopic and microscopic scales.

Why is Dynamic Traffic Assignment Used

The first three steps of a typical four-step travel demand model (trip generation, distribution, and mode choice) "address travelers' long-term decisions and determine the overall level of travel in the network. For instance, based on the location of households and businesses within traffic analysis zones, the first two steps help to establish the long-term OD matrix. Modal split analysis can be considered as - transition analysis between long and short-term planning"[1]. Not only does transit use depend on long-term planning (location and how travelers perceive various modes), but it also depends on short-term changes to the transportation system such as the availability of other modes of travel.

Many transportation projects involve comparisons between alternatives or determining reasonable mitigations/improvements for a given a set of short or long-term decisions (i.e. home and job locations). Often times other transportation projects and areas of public interest (i.e. education, public safety, etc) compete for the same funding thus; having a well balanced transportation system that best utilizes the economic, environmental, and other resources is critical. DTA can be one tool to assist in the decision making process by taking a pure demand that excludes delay from queues and ignores the time it takes to physically travel, and turning it into a more reasonable "constrained" demand and/or shifting the excess demand to alternate routes.

Rather than accounting for delay associated with queues and creating new routes, the traditional model ignores since it does account for congestion by reducing the speed as the volume goes up. For example, a typical demand model may forecast extremely high link and turn movements exiting a freeway at very low speeds because the volume-to-capacity ratio. These vehicles would continue along their path to their destination, impacting all the roadways and intersections along the way when the reality would be either the vehicles are in a queue on the mainline (holding up others trying to exit or continue through on the freeway) or would take an alternate route which impacts other locations. With a limited funding source, it might not be feasible to improve the ramps and mainline so the decision makers may choose to improve the local street intersections based on the high volumes. This situation might result in improvements at some locations (along the resulting paths from the static assignment) and not others (actual paths or paths from dynamic assignment).

A similar situation might occur if the trips at a certain location would not actually exist in the period of study since the distance of travel would result in a later arrival. For example, there might be peak hour trip that is being modeled and the distance to travel might be 90 miles; even under free-flow conditions there is no way to get there in the peak hour unless the free-flow speed is 90 mph, but traditional models allow the trip to start and end during the hour. The traditional demand model has no concept of time, just a cost it needs to minimize.

Another benefit of dynamic assignment is the responsiveness to removing bottlenecks and showing what happens downstream or at other locations that were previously used as alternate routes. Static assignments provide information to help answer "what should we build, where should we build it, and how large should it be?"; dynamic assignment gives provides information to help answer "where are the critical locations, what are the alternative routes, how much are people willing to pay to avoid congestion, and how bad are the queues?". A comparison of static and dynamic assignment for congestion pricing found that "traditional static models have the potential to significantly underestimate network congestion levels in traffic networks, and the ability of DTA models to account for variable demand and traffic dynamics under a policy of congestion pricing can be critical"[2].

How Might Dynamic Traffic Assignment be Implemented

Implementing DTA in traditional travel demand models will address many of the issues mentioned previously. Utilizing both standard travel demand model outputs (usually origin-destination tables) and microsimulation models will help determine the impacts of queuing, travel time, vehicle interactions, and other characteristics of the network. Calibration and validation of both a demand model and an operations microsimulation model requires a lot of time and data, but the process is usually focused on a limited study area. Not only does the setup of this process take time, but micorsimulating each vehicle traveling through the network also takes much longer than the typical demand model assignment. Microsimulation handles the impact of queuing, but if the origin-destination matrix is obtained from a congested network or a large network where vehicles in the study area could not travel to, or through, during the study period, the operational results might be much different than if using the "constrained" demand (try breaking this long sentence into two parts). The results might lead to over designing some locations and under designing others or using resources that could be better spent on something else.

Some of the applications for DTA include:

- Evaluate the impacts of congestion relief strategies, such as infrastructure expansions, on large networks.
- Plan road, ramp, and lane closures for maintenance and construction projects.
- Model managed lanes/congestion pricing strategies.
- Evaluate signal control plans by modeling how drivers will adapt their route choices.
- Assess the impacts of advanced transportation management systems (ATMS) or intelligent transportation systems (ITS).
- Determine detours and policies in response to incidents, the loss of critical infrastructure, and mass evacuations.

Another interesting approach possible with DTA relates to departure times and peak spreading. Traditional models (and most DTAs at the current time) do not account for the time the purpose of the trip needs to occur. In reality, many trips depart at a time such that the traveler arrives at a specific location at a specific time and not because of a desired departure time. For example, an employee starts work at 7 AM and lives 30 miles away from the office. Under free-flow conditions, they might leave for work around 6:30 am and get there on time. If they lived 90 miles away or there was major congestion that took an extra hour, they would need to leave earlier (i.e. in a different modeling peak hour). DTA utilizes a departure distribution profile and this profile can be based on the congested travel time, allowing the departure time to change to arrive at the specified time. This is similar to the destination choice concept for trip distribution, except it is temporal instead of spatial.

Utilizing DTA in the travel model adds the ability to perform this type of analysis on a larger network that recognizes how all the parts are connected and how they affect one another in space and time. The lack of a connection between space and time is the major limitation of the four-step models that could be addressed by integrating operational simulation models on a smaller scale but at a higher cost, and longer time. Although DTAs don't provide the same level of microscope detail as operational microsimulations, they largely overcome the time and cost issue and provide a tool that can operate effectively for even large networks. However, DTA can have a larger network than an operational microsimulation since the detail and run time are much lower.

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[1] "Development of a Dynamic Traffic Assignment System for Short-Term Planning Applications" Thesis by Srinivasan Sundaram. Massachusetts Institute of Technology, June 2002.

[2] "A Comparison of Static and Dynamic Traffic Assignment Under Tolls: A Study of the Dallas-Fort Worth Network " Boyles, Ukkusuri, Waller, and Kockelman. August 1, 2005.