Travel Time Reliability in Regional Transportation Planning

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Abstract

Travel time reliability is an important measure of congestion and can serve as baseline for prioritizing improvements into a region's transportation system. This paper begins with a literature review of travel time reliability and its value as a congestion measure. It then presents the methodology and results of a content analysis of twenty regional transportation plans from across the nation. This analysis concludes that travel time reliability is not currently used as a congestion measure, and that the most common measures of congestion were the volume-to-capacity ratio, vehicle hours of delay, and average speed. The paper then uses data from Portland, Oregon to provide a case study for how to prioritize roadways according to travel time reliability measures. Conclusions from the case study were that I-84 West should be prioritized in the AM peak, and that I-405 South should be prioritized in the PM peak. This paper ends by recommending to metropolitan planning organizations that they use travel time reliability in the following ways: 1) incorporate it as a system-wide goal; 2) evaluate roadway segments according to travel time reliability measures; and 3) prioritize roadway segments using those measures.

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Introduction

Transportation planning has traditionally been structured in three distinct and interdependent steps: 1) evaluation of the current transportation system, 2) projection of future usage of the transportation system, and 3) identification and prioritization of investments into the transportation system based on current measures and projections of future usage (1). Planners have followed these steps to engage in the systematic creation and updating of transportation plans within federal, state, regional, and local governments. In both the first and the third steps, planners use measures of congestion, accessibility, mobility, connectivity, and safety to evaluate the transportation system's health and determine where future investments are needed. This paper will take a close look at how measures of congestion are used in that evaluation and will suggest that the addition of travel time reliability measures to the ones currently in use can result in a better understanding of the transportation system.

Planning at each level of government is important to the health and vitality of our urban systems, but planning at the regional level is perhaps the most crucial. Metropolitan regions have become key economic forces in the United States, and transportation networks are regionally oriented systems. The U.S. Department of Transportation recognized the regional nature of transportation networks in the creation of Metropolitan Planning Organizations (MPOs), and in requiring the allocation of federal transportation dollars on a regional basis. MPOs are required to distribute these funds regionally and to document their rationale in a Regional Transportation Plan (RTP) which must be updated every four years. MPOs have some flexibility in the structure of their RTPs, but are guided by legislation from the federal government as to the necessary content.

This paper will discuss specific ways in which the transportation system is evaluated for congestion during the process of regional transportation planning. The paper will discuss commonly used measures of congestion as well as a measure that is currently not in frequent use—travel time reliability—with the goal of proving the importance and relevance of travel time reliability measures for regional planning. It will begin by elaborating on the differences between currently used measures of congestion as used in transportation planning and travel time reliability, the definitions and measures of travel time reliability, and the importance of travel time reliability as a measure of congestion. It will describe the methodology and results of a content analysis performed on a random sample of regional transportation plans from across the nation that focused on uses of reliability within each plan. It will then discuss travel time reliability in the context of the Portland, Oregon metropolitan region with a case study of instrumented Portland freeways according to their travel time reliability ratings. Finally, this paper will provide recommendations to metropolitan planning organizations on how to incorporate measures of travel time reliability into their regional transportation plans.

Literature Review

Measures of Congestion used in Transportation Planning

Measures of congestion are intended to evaluate the performance of the transportation network and to diagnose problem areas. They provide information on how well the system has met certain stated goals and targets, and can also help to explain variations in user experiences of the system. There are four general categories of congestion measures (2). The first category contains measures that explain the duration of congestion experienced by users in some way; these include delay, risk of delay, average speed, and travel time. The next category includes measures that analyze how well the system is functioning at a given location. This category primarily consists of the volume-to-capacity (V/C) ratio, which is usually expressed as a level-of-service (LOS) category. LOS is a performance rating that is often used as a technical way to express how well a facility is functioning. For example, a facility functioning poorly is likely to be rated as LOS F, but could just as easily be described as "poor." The third category is that of spatial measures, including queue length, queue density, and vehicle miles traveled. It is important to note that some of the duration and spatial measures are actually measured as point measures. The final category of measures is the "other" category, consisting primarily of travel time reliability and the number of times a vehicle stops because of congested conditions (2).

Easily the most common measure of traffic congestion is the volume-to-capacity ratio. The V/C ratio measures the number of vehicles using a facility against the number of vehicles that the facility was designed to accommodate. This ratio is an important measure for planners to use, and represents an easily understandable measure of whether or not a roadway is congested. However, it can lead to some philosophical problems, such as whether transportation systems should be built to handle the highest demand or the average demand, and what level of service is acceptable. In addition, it is difficult to accurately measure the capacity of a roadway. The volume-to-capacity ratio is an important tool for comparing a roadway's performance to other roadways and over time, but does not necessarily reflect the overall user experience and values in the system (1).

Despite the prevailing usage of the volume-to-capacity ratio, and perhaps because of its inherent philosophical difficulties, the FHWA has strongly encouraged agencies to consider travel time experienced by users as the primary source for congestion measurement (3). They also state that currently used measures of congestion are inadequate for determining the true impact of the congestion that clogs up the transportation system from a user's perspective, and that they are not able to adequately measure the impacts of congestion mitigation strategies (4).

Definitions and Measures of Travel Time Reliability

Travel time reliability is a measure of how dependable the travel time on a given roadway is. Measures of travel time reliability attempt to quantify both the variability in travel times across different days and months and the variability across different times of day. Travel time reliability is an alternative to the volume-to-capacity ratio, and can greatly help to determine the adequacy of the service provided by a transportation network (5). Whereas the V/C ratio focuses specifically on the need to design for a capacity that will meet the demand on a roadway, and therefore tends to lead to recommendations to build more roadways, travel time reliability measures are oriented towards better management of the existing system.

According to the Federal Highway Administration, there are six standard measures of travel time reliability. The basis for all of the measures is route or point-to-point travel times, and there are four main data sources from which travel time estimates can be developed: directly calculated from continuous probe vehicle data; estimated from continuous point-based detector data; collected in periodic special studies; or estimated using computer simulations (6). Reliability calculations for this study have been made using point-based detector data that has been archived in the Portland Oregon Regional Transportation Archive Listing (PORTAL) since July of 2004. The FHWA-accepted measures of travel time reliability are the following:

- *90th or 95th Percentile Travel Time*: in other words, out of 100 travel times on a given corridor, the 90th or 95th longest.
- *Travel Time Index*: the average amount of time it takes to travel during peak hours compared to free flow conditions computed as average travel time divided by free flow travel time.
- *Buffer Index*: the extra time that travelers add to travel to make sure they are on time most of the time, computed as the difference between the 95th percentile travel time and the average travel time, divided by average travel time.
- *Planning Time Index*: the total time needed to plan for an on-time arrival 95% of the time, computed as 95th percentile travel time divided by free-flow travel time.
- *Frequency that congestion exceeds some expected threshold*: the percentage of days when the average travel speed falls below a certain value, or the number of days when travel time is higher than a certain number of minutes.

This study uses the buffer index as the primary measure of travel time reliability because it is nuanced enough to give a percentage that travelers can relate to and is more likely than congestion frequency or the travel time index to reflect the kinds of decisions that travelers make. For example: if a traveler knows that the travel time at midnight on a given roadway is ten minutes and she or he wishes to use that same roadway at 4 PM, then knowing that the buffer index on that roadway at 4 PM is 30% will allow that traveler to make a well-informed decision to allow thirteen minutes of travel on the roadway at that time.

Researchers differ from the FHWA on how to accurately define and measure travel time reliability. Emam and Al-Deek asserted that travel time reliability can be defined as the probability that a trip between a given Origin-Destination pair can be made successfully within a specified time interval (7). They created a new model to estimate travel time reliability that more accurately reflected departure time. However, Van Lint and Van Zuylen state that the reliability of a given route is a function of the time of day, the day of the week, the month of the year, and external factors such as congestion. According to those authors, the wider the distribution of travel times, the more unreliable the corridor is. They argue that travelers prefer routes with higher mean travel times and smaller travel time variation, to routes with a lower mean travel time and larger variability (8). Other researchers state that the best definition of travel time reliability is the percent of similar trips (in terms of trip purpose and time of day) that occur within a given range of travel times (9).

Value of Travel Time Reliability as a Measure of Congestion

Travel time reliability measures can be used as a valuable supplement to existing measures of congestion in the transportation system. Many transportation professionals have begun to realize the importance of evaluating travel time reliability, particularly for commuters and industries that depend on definite travel times to deliver their goods (2). Recker, Liu, and Xiaozheng assert that the reliability of a given route is an important determinant of mode choice for individuals, and that travelers perceive travel time in terms of mode. For example, using a logit model-based evaluation of traveler survey data, they found that the cost of travel delay for taxi users was much higher than for car users.

Those researchers explain that non-recurring congestion is a major factor affecting travel time reliability (10).

Chen and Skabardonis similarly state that travel time reliability is “an important measure of service quality for travelers” (11). They argue that travel time reliability can be used to gauge the benefits of intelligent transportation systems investments and can also be used as a measure of freeway service quality that is superior to Level of Service. Using travel time data from I-5 in Los Angeles and a formula for quantifying travel cost, they argue that incidents have a measurable effect on travel time, and that unexpected delays are more costly to travelers than expected delays. Shao, Lam, Meng and Tam similarly assert, based on a demand-driven model that they created for their study, that travelers consider not only the average travel time but also the reliability of a given route when choosing a route (12). Other researchers add to this, and state that presenting anticipatory travel time information in route guidance systems and trip planners can help to improve freeway network performance (13). Still others state that guaranteeing a given travel time on a tolled roadway segment can greatly increase the political viability of instituting tolled roadway segments due to the high value that travelers place on travel time reliability (14). Nam, Park, and Khamkongkhun argue that travelers’ tastes for travel time and reliability vary across times of day, and that route choice is based on a combination of travel time, travel time reliability, and cost. Using a discrete choice modeling approach, they argue that reliability is most important closest to the start-time of the traveler’s workday though travel time reliability is a useful measure at all hours (15).

The importance of travel time reliability has also begun to gain attention within the Portland, Oregon metropolitan region with the recent publication of the report entitled, "The Cost of Congestion to the Economy of the Portland Region." The report states that travel time reliability is of critical importance to businesses and industries within the Portland region, and presents an investment scenario that could improve overall congestion conditions and travel time reliability in particular (16).

Conclusion

While travel time reliability has not historically been used to measure congestion levels within a metropolitan area, recent academic literature and publications from the U.S. Department of Transportation suggest that professionals are looking more and more to travel time reliability to provide a more accurate picture of the transportation system. Recent reports indicate that travel time reliability is beginning to gain attention within the Portland region as well.

Research Design

Research Questions

This paper uses a content analysis of RTPs and a case study of Portland freeways to address the following questions:

- How do Metropolitan Planning Organizations measure congestion, and do they use travel time reliability?
- How do freeway segments in Portland compare to each other in terms of travel time reliability?
- Have these travel time reliability ratings changed over time?

- How can MPOs use travel time reliability in their planning processes?

RTP Content Analysis

The regional transportation plans studied as part of this analysis were selected to represent geographic diversity and a range of population sizes. A total of twenty RTPs were selected for this study representing approximately 5% of the 382 total MPOs in the nation. All RTPs were downloaded from the corresponding MPO's website. A listing of each MPO studied and its website address can be found in the reference section of this paper. The comprehensive list of MPOs given by ssociation of Metropolitan Planning Organizations was used as the basis for the random selection of RTPs.

Table 1 lists each MPO included in this study, the jurisdictions it includes, and the 2000 population of those jurisdictions.

Table 1: Description of MPOs

	Metropolitan Planning Organization	**Region**	**2000 Population***
1	Baltimore Metropolitan Council	Baltimore, Anne Arundel, Carroll, Harford, and Howard Counties, MD	2,520,000
2	Bonneville Metropolitan Planning Organization	Bonneville County, ID	78,356
3	Chittenden County Metropolitan Planning Organization	Chittenden County, VT	146,571
4	Durham-Chapel Hill-Carrboro Metropolitan Planning Organization	Chatham, Durham, and Orange Counties, NC	390,870
5	Houston-Galveston Area Council	Houston-Galveston, TX	4,669,571
6	Indian Nations Council of Governments	Tulsa, OK	859,532
7	Madison Area Metropolitan Planning Organization	Dane County, WI	426,526
8	Maricopa Association of Governments	Maricopa County, AZ	3,072,149
9	Metro	Multnomah, Washington (partial), and Clackamas (partial) Counties, OR	1,444,219
10	Metroplan Orlando	Orange, Osceola, and Seminole Counties, FL	1,440,135
11	Metropolitan Council	Minneapolis and St. Paul, MN	2,642,056

	Metropolitan Planning Organization	Region	2000 Population*
12	Mid-Ohio Regional Planning Council	Delaware County, Franklin County, Bloom township, Violet township, Etna township, and Pataskala, OH	1,178,618
13	Mid-Region Council of Governments	Bernalillo County, NM	622,314
14	Montgomery Area Metropolitan Planning Organization	Montgomery (partial), Elmore (partial), and Autaga (partial) Counties, AL	350,700
15	Nashville Area Metropolitan Planning Organization	Davidson, Rutherford, Sumner, Wilson, and Williamson Counties, TN	1,099,608
16	New York Metropolitan Transportation Council	New York City, Staten Island, and Lower Hudson Valley, NY	12,200,000
17	North Central Texas Council of Governments	Dallas and Fort Worth, TX	4,989,750
18	Regional Transportation Council of Southwest Washington	Clark County, WA	345,238
19	San Diego Association of Governments	San Diego, CA	2,813,833
20	Tri-County Regional Planning Commission	Dauphin, Cumberland, and Perry Counties, PA	509,074

*Source: U.S. Census Bureau, 2000

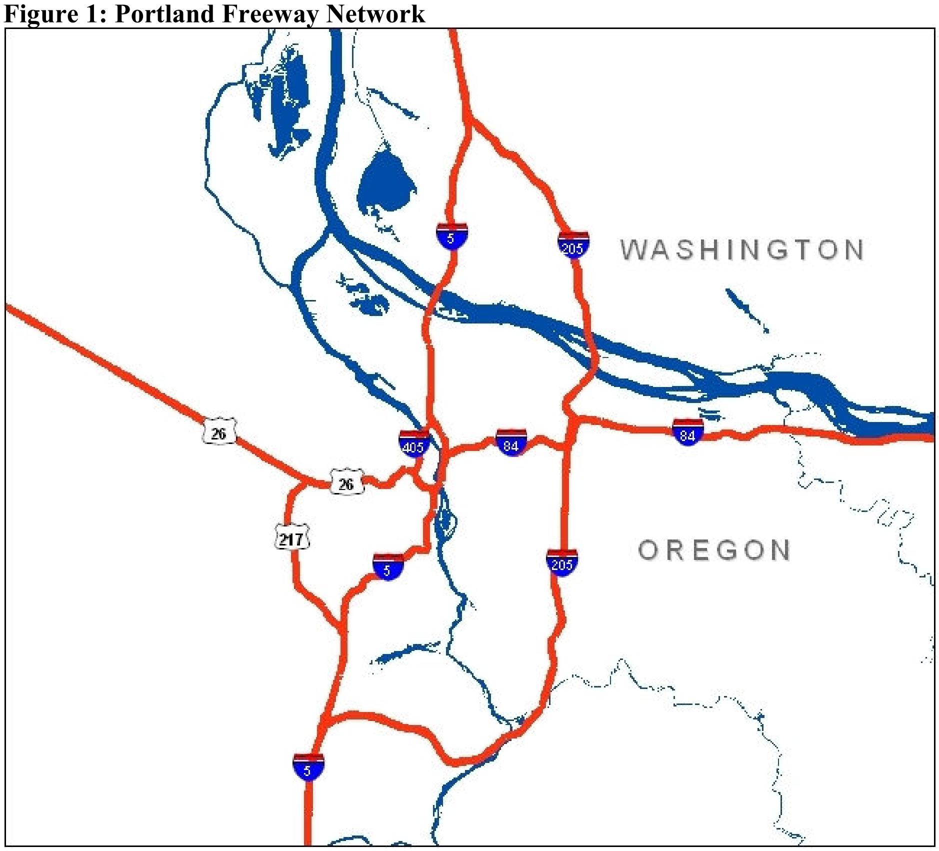
Travel Time Reliability Case Study

The Portland, Oregon Regional Transportation Archive Listing (PORTAL) serves as the Archived Data User Service for the Portland region. The purpose of PORTAL is to collect and archive loop detector data from all detectors on the freeway network and analyze them for congestion patterns. This study used data archived by PORTAL at http://portal.its.pdx.edu for the case study analysis of travel time reliability in the Portland region. Currently, PORTAL uses the 95th percentile travel time, the buffer index, and the travel time index as its measures of travel time reliability.

The data included average monthly travel time in 5-minute increments, average 95th percentile travel time in 5-minute increments, and free flow travel time. Monthly data downloaded from PORTAL was aggregated into yearly averages for each roadway segment at each year. These averages were used to create the buffer indices detailed in the case study chapter. Data was downloaded directly from the PORTAL website for each month available (July 2004 through April 2007) on the entirety of each freeway segment.

Figure 1 shows a map of the Portland freeway network. Eleven total freeway segments were studied, including: I-5 North and South; I-84 East and West; I-205 North and South; Highway 217 North and South; Highway 26 East and West; and I-405 South. There was no data available for I-405 North at the time of this study. The specific segments of each freeway were determined by the locations of the two detector stations that are farthest from each other. The collected data can be assumed to be of fairly high quality, though it could have been affected by situations such as detector outages.

Figure 1: Portland Freeway Network



Analysis of Regional Transportation Plans

Overview and General Themes

Most metropolitan planning organizations did not use travel time reliability as a congestion measure within their most current regional transportation plans. Many of them mentioned reliability within the components of other goals, such as transit service reliability as part of a goal of increasing overall transit ridership or freight service reliability as part of a goal of improving freight connectivity in the region, but few used travel time reliability as a system-wide goal for all modes.

Every MPO studied used the V/C ratio as its primary measure of congestion on its roadways and most used it to prioritize roadways for capacity improvements. Some MPOs listed other congestion measures, such as vehicle hours of delay or travel time to work, in their analyses. Others used vehicle miles traveled per capita, person hours of travel, or average peak hour speed. Many of the data used and created for these measures could easily translate into a travel time reliability measure, leaving little need for further data collection and only minimal additional data analysis for regional transportation planners.

Description of Plans

This section will provide a brief narrative description of each plan studied, focusing specifically on the congestion and system performance measures it described, its investment prioritization process, and any discussion (or lack thereof) of travel time reliability.

1. Baltimore Metropolitan Council (MD): *Transportation 2030*

This plan discusses system measurements of person-hours of delay and growth in total vehicle miles traveled by corridor. The plan also shows a map that describes congested corridors according to average speed (congestion determined by each road type), and discusses average travel time to work by year. A congested corridor is one in which the level-of-service is E or F. System investments in this plan were based on the technical analysis of congestion levels, accident rates, and number of users. Investments in Intelligent Transportation Systems are expected to improve congestion. This plan does not specifically address travel time reliability.

2. Bonneville Metropolitan Planning Organization (ID): *Long Range Transportation Plan*

This plan uses the volume-to-capacity ratio-based level-of-service measures as its exclusive measure of congestion. The plan sets a goal of maintaining LOS C on all roadways. Projects are prioritized in this plan according to the capacity provided, environmental concerns, and cost. In general, this is an area with low population growth and low congestion. This plan does not discuss reliability except as it relates to transit service reliability.

3. Chittenden County Metropolitan Planning Organization: *Chittenden County Metropolitan Transportation Plan*

This plan measures congestion exclusively by the volume-to-capacity ratio which leads to a qualitative description of each roadway as “good,” “bad” or “fair.” The plan discusses the projected future average peak-hour speed and future VMT as other system performance measures. System efficiency measures included cost of trip and total time of trip. The plan sets forth a goal of minimizing cost and travel time for people and goods, but currently has no discussion of reliability.

4. Durham-Chapel Hill-Carrboro Metropolitan Planning Organization: *2030 Long Range Transportation Plan*

This plan sets LOS service standards for each functional class of roadway. Reduced congestion, measured by the volume-to-capacity ratio, is a goal of some projects in this plan. System improvements are prioritized based on ability to meet LOS goals, safety goals, and work within environmental and social constraints. This plan has no discussion of reliability.

5. Houston-Galveston Area Council: *2025 Regional Transportation Plan, Houston-Galveston Area*

This plan uses the volume-to-capacity ratio as its basis for defining congestion. This leads into an overall “Level of Mobility" analysis by corridor and for the entirety of the system. It also looks at peak travel time contours system-wide and by roadway. This plan focuses on improving congestion through expanding roadway capacity. It does not discuss travel time reliability.

6. Indian Nations Council of Governments: *Destination 2030 Long Range Transportation Plan*

This plan states that congestion measures are subjective and must be defined locally. The two measures used for this region are the volume-to-capacity ratio and average observed travel speed. Interestingly, it states that current congestion levels in this area are acceptable. Improvements are prioritized in this plan based on projected future congestion levels. This plan only discusses reliability in the context of the need to preserve it on grade crossings and bridges, particularly when undergoing maintenance on those facilities. Travel time reliability is not used as a performance measure or in investment prioritization.

7. Madison Area Metropolitan Planning Organization: *Regional Transportation Plan 2030*

Congestion is defined in this plan using the volume-to-capacity ratio as an indicator for level of service; more specifically, congestion is LOS D or E. This plan discusses congestion management measures within the overall transportation system management program. One of the goals of freeway management within the transportation system management program is an improvement in travel time reliability. Reliability improvements are also mentioned as goals of the intelligent transportation systems program. Overall, this plan is advanced in its usage of travel time reliability as a goal of multiple programs, but it does not give a performance measure for assessing travel time reliability improvements.

8. Maricopa Association of Governments: *Draft Regional Transportation Plan 2007 Update*

The measure of congestion used in this plan is the volume-to-capacity ratio expressed as a level of service. This plan also uses travel time as a performance measure. One of the major goals of the plan is to maintain reasonable travel times. Improved reliability is stated as a one of the goals of intelligent transportation systems projects and the larger freeway management program. Overall, the only discussion of travel time reliability in this plan is in the context of ITS projects.

9. Metro: *2004 Regional Transportation Plan*

This plan uses a volume-to-capacity defined level-of-service as the operating standard for freeways, central cities, corridors, and other areas. It describes a preferred standard, acceptable standard, and deficiency standard by each roadway type. This plan analyzes the roadway system based on the number of average weekday trips, system VMT, motor vehicle speed, average travel time, miles of congestion per roadway, vehicle hours of delay, and mode split. Investments are prioritized according to their compliance with land use goals and objectives, their ability to reduce vehicle miles traveled, and other factors. This plan does not discuss travel time reliability.

10. Metroplan Orlando: *Year 2025 Long Range Transportation Plan*

This plan measures congestion by the volume-to-capacity ratio and vehicle hours of delay. Other highway system performance measures include: total system lane miles, total miles of deficient roadways, vehicle miles traveled per capita, vehicle hours traveled per capita, and access to activity centers. Investments were prioritized primarily through public involvement, and congestion is one of the primary concerns of the public.

11. Metropolitan Council: *2030 Regional Transportation Plan (within the Transportation Policy Plan)*

This plan measures congestion using a level-of-service defined by the volume-to-capacity ratio. It discusses the goal of providing transit service reliability, but does not discuss reliability of roadways. Reliability is not used as a strategy for prioritizing system improvements.

12. Mid-Ohio Regional Planning Council: *2030 Transportation Plan*

Unlike most other plans, this plan uses vehicle hours of delay as its primary congestion measure. It also quantifies congestion in terms of wasted fuel and lost productivity. It uses the following measures of system efficiency: peak travel speed, person hours of travel, level of service measured by the volume-to-capacity ratio, service to an intermodal facility, and truck percentage. This plan does state that improving reliability and reducing overall delay is a goal of the system improvements. This plan does well in incorporating such goals but does not include performance measures of travel time reliability.

13. Mid-Region Council of Governments: *Metropolitan Transportation Plan*

This plan measures congestion exclusively through the volume-to-capacity ratio. It also uses peak hour delay and vehicle miles traveled as performance measures. This plan does state that improving travel time reliability is an overall goal of the system improvements. However, these improvements were evaluated based on vehicle miles traveled and hours of travel added to the system, percent of congested miles traveled during the PM peak, and benefit/cost ratio, and not by travel time reliability measurements. This plan also discusses improved travel time reliability as a byproduct of intelligent transportation systems investments.

14. Montgomery Area Metropolitan Planning Organization: *Montgomery Study Area 2025 Long Range Transportation Plan*

This plan uses the volume-to-capacity ratio to model system improvements, but does not elaborate on current conditions. The design standard for new roadways in this plan is LOS D. Capacity deficiencies are identified through the modeling process and the new projects identified are exclusively corridor widening projects and new interchanges. This plan does not discuss travel time reliability.

15. Nashville Area Metropolitan Planning Organization: *2030 Long Range Transportation Plan*

This plan defines congestion according to the volume-to-capacity ratio. Other system performance measures include: average route speed, transit delay, vehicle miles traveled per licensed driver, vehicle occupancy, citizen complaints, and projected average route speed. Roadways with the worst congestion as defined by those performance measures were given priority for investment. This plan also used average route speed to compare peak travel times to off-peak travel times, which can be used as a measure of travel time reliability but was not a factor in project prioritization. The plan also stated the reliability related goal of minimizing roadway service interruptions.

16. New York Metropolitan Transportation Council: *2005-2030 Regional Transportation Plan*

This plan measures congestion using the volume-to-capacity ratio-defined level-of-service categories. It also uses travel times by mode as a measure of mobility. One sub-goal of the plan is to improve the reliability of the transportation system by improving service coverage and ease of use. The plan document concludes by asserting that the improvements listed will help reliability in the region, though the plan does not use any specific measures of reliability in project prioritization.

17. North Central Texas Council of Governments: *Mobility 2025*

This plan measures congestion primarily using the volume-to-capacity ratio-defined level-of-service categories, but also uses person-hours of delay. The plan states a goal of reducing congestion and improving travel times in the region but givers no specific performance measures. This plan discusses the need for reliability of freight movement, but does not specifically discuss reliability for other modes.

18. Regional Transportation Council of Southwest Washington: *Metropolitan Transportation Plan*

This plan uses a corridor congestion index, which is defined by the system-wide benchmarks of average peak hour speed, vehicle miles traveled in the PM peak hour, lane miles of congestion (based on a volume-to-capacity defined level of service category of E or F), and vehicle hours of delay. Washington State requires a LOS standard to be maintained for each roadway and these are described as travel times in the plan. Capacity expansions are prioritized based on capacity needs and safety issues. In general, this plan mentions reliability a couple of times but does not use it as a goal or performance measure.

19. San Diego Association of Governments: *Mobility 2030*

This plan uses several performance measures of congestion, including: average work trip travel time, average daily travel time, average work trip travel speed by mode, and volume-to-capacity based level-of-service categories. It discusses congestion both on a daily and peak hour basis. The plan includes a travel time monitoring schematic depicting travel time differences between existing, no build, and build scenarios for major commuting routes. System reliability is a major policy goal of the plan, and is seen as a byproduct of improved application of technology. The plan states that decreases in congestion resulting from planned investments will result in increases in reliability. Alternatives are evaluated using LOS, peak volumes by mode, and travel times by mode on a corridor-by-corridor basis. In general, reliability is discussed as a major goal of the plan, but no specific performance measures are given.

20. Tri-County Regional Planning Commission (PA): *2030 Regional Transportation Plan—2007 Update*

This plan uses the volume-to-capacity defined level of service categories as its primary measure of congestion. It discusses the possibility of using intelligent transportation systems technologies to improve roadway system reliability and reduce overall congestion. The plan discusses reliability in terms of transit service, but not in the context of other modes.

Summary of Findings

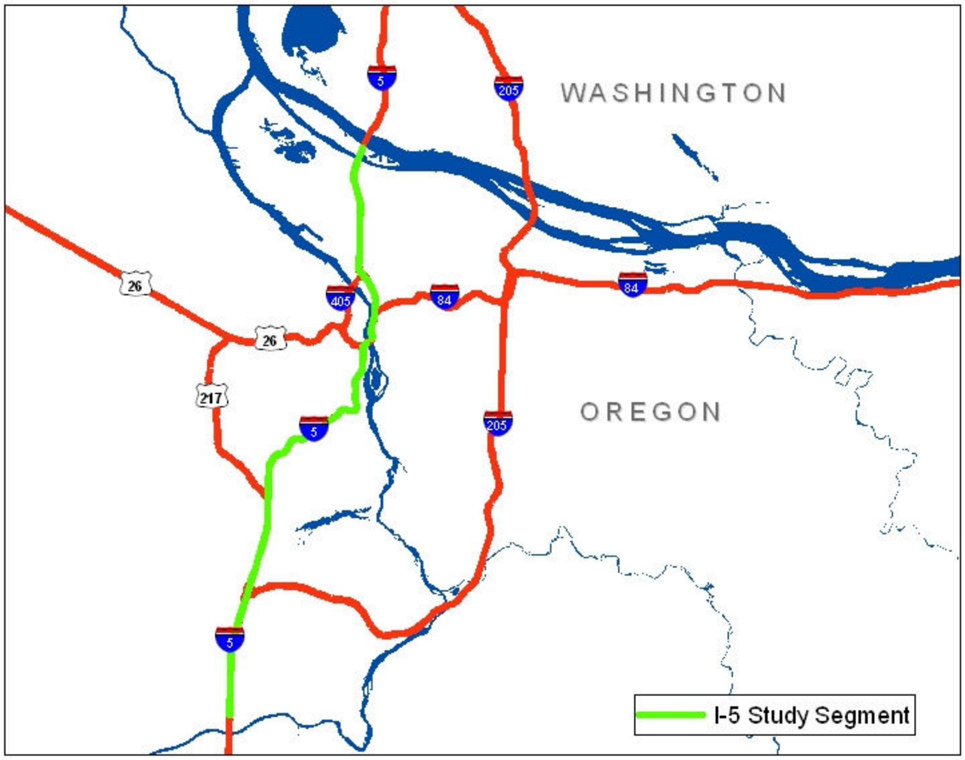
Five of the twenty MPOs used travel time reliability as a goal of their transportation system performance, but none of them used reliability as a specific performance measure. Many could easily do so given the data they already use for their existing congestion measures. For example, raw travel times can easily be converted to the buffer index if it is possible to compute both the average travel time in a corridor and the 95th percentile travel time.

According to this sample, RTPs do not tend to vary in their usage of travel time reliability according to geography or regional population size. None of the RTPs used reliability in a comprehensive way within the document, although a few set forth overarching goals of improving regional travel time reliability. Many plans did discuss measures related to reliability such as average travel time or subsets of reliability such as transit service reliability, and need only to state more clearly the need to create a reliable system for all modes in their next updates.

Case Study: Travel Time Reliability in Portland, Oregon

The purpose of this case study is to evaluate and compare all major freeway segments within the Portland, Oregon metropolitan area according to travel time reliability, and in doing so provide a model for how MPOs could use travel time reliability to prioritize roadways for improvements. The following freeways have been analyzed for all months between July 2004 and April 2007. Maps showing the study segments for each freeway are provided below.

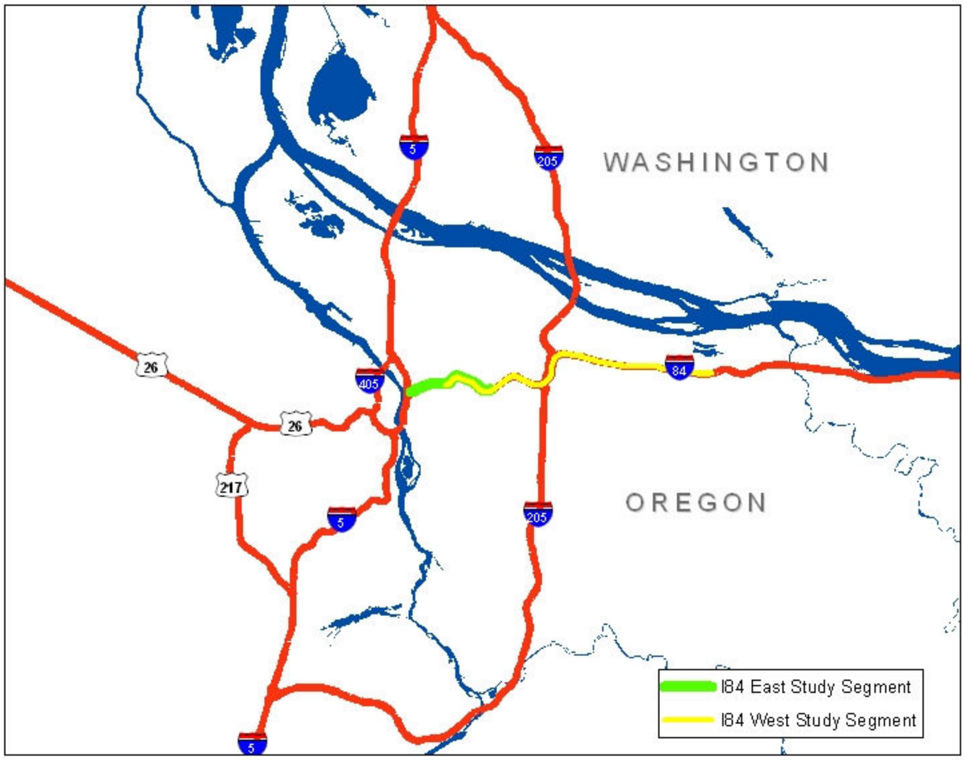
Figure 2: I-5 Study Segments



- I-5 North from mile 283.83 to mile 307.9 (Wilsonville to Jantzen Beach; 24.07 miles total)

- I-5 South from mile 307.9 to 289.38 (Jantzen Beach to Wilsonville; 18.52 miles total)

Figure 3: I-84 Study Segments



- I-84 East from mile 0.1 to 3.55 (Morrison Bridge to 60th; 3.45 miles total)
- I-84 West from mile 2.1 to 14.43 (33rd to 207th; 12.33 miles total)

Figure 4: I-205 Study Segments

- I-205 North from mile 3.55 to 23.41 (Stafford Road to Columbia Boulevard; 19.86 miles total)
- I-205 South from mile 2.86 to 24.77 (Airport Way to Stafford Road; 21.91 miles total)

Figure 5: Highway 217 Study Segments

- Highway 217 North from mile 0.66 to 2.71 (72nd Avenue to Walker Road; 2.05 miles total)
- Highway 217 South from mile 0.08 to 7 (Barnes Road to 72nd Avenue; 6.92 miles total)

Figure 6: Highway 26 Study Segments

- Highway 26 East from mile 58.8 to 73.71 (Jackson School Road to I-405 Count Station; 14.91 miles total)

- Highway 26 West from mile 64.24 to 73.41 (185th to I-405 Count Station; 9.17 miles total)

Figure 7: I-405 Study Segments

- I-405 South from mile 0.55 to 4.09 (Front Ave to I-405 SB Data Station; 3.54 miles total)

There are only two detector stations on I-405 North, and they are too closely spaced to provide an accurate measure of travel time, so it has not been included in this study.

The buffer index was chosen as the primary measure of travel time reliability used for this study. It is calculated by subtracting the 95th percentile travel time from the average travel time, and then dividing that result by the average travel time so as to represent the percentage of extra travel time that most people would need to add on to their trip in order to ensure on-time arrival. For example, a buffer index of 50% at 5 PM on a freeway whose travel time is ten minutes at midnight (when there's no congestion) would indicate that the traveler should allow for 15 minutes at 5 PM to make sure that he or she is on time. Table 1 details the buffer index values for each freeway segment for

2004 to 2007. Because data is not available for the full years of 2004 and 2007, values from those years should be used with some caution. This table also includes a qualitative rating for each freeway, the ratings are: very poor (average daily index of above 30%), poor (average daily index of between 25%-29%), average (average daily index of between 20%-24%), and good (average daily index of up to 19%).

Table 2: Buffer Index Values

		Daily	PM Peak (4-6 PM)	AM Peak (7-9 AM)	Rating
I-5 NORTH	2004	22%	68%	33%	Average
	2005	22%	68%	36%	
	2006	26%	68%	45%	
	2007	24%	63%	42%	
	Average	24%	67%	39%	
I-5 SOUTH	2004	26%	68%	46%	Average
	2005	21%	60%	34%	
	2006	22%	75%	34%	
	2007	22%	64%	37%	
	Average	23%	67%	38%	
I-205 NORTH	2004	15%	60%	17%	Good
	2005	17%	58%	28%	
	2006	19%	65%	36%	
	2007	19%	57%	40%	
	Average	17%	60%	30%	
I-205 SOUTH	2004	17%	66%	34%	Good
	2005	20%	54%	50%	
	2006	20%	59%	47%	
	2007	16%	44%	43%	
	Average	18%	56%	43%	
I-405 SOUTH	2004	20%	101%	21%	Poor
	2005	27%	136%	19%	
	2006	28%	133%	21%	
	2007	32%	130%	23%	
	Average	27%	125%	21%	
I-84 EAST	2004	25%	85%	7%	Average
	2005	23%	77%	9%	
	2006	22%	77%	11%	
	2007	24%	82%	20%	
	Average	24%	80%	12%	
I-84 WEST	2004	37%	55%	86%	

		Daily	PM Peak (4-6 PM)	AM Peak (7-9 AM)	Rating
	2005	38%	47%	84%	
	2006	36%	56%	89%	
	2007	36%	111%	74%	
	Average	37%	67%	83%	
HWY 217 NORTH	2004	16%	41%	31%	Good
	2005	17%	49%	42%	
	2006	24%	58%	53%	
	2007	21%	50%	47%	
	Average	20%	49%	43%	
HWY 217 SOUTH	2004	29%	94%	58%	Poor
	2005	28%	97%	46%	
	2006	31%	100%	48%	
	2007	26%	97%	46%	
	Average	28%	97%	50%	
HWY 26 EAST	2004	38%	96%	73%	Very Poor
	2005	35%	75%	73%	
	2006	32%	89%	67%	
	2007	33%	70%	83%	
	Average	34%	83%	74%	
HWY 26 WEST	2004	27%	50%	42%	Poor
	2005	29%	45%	59%	
	2006	17%	44%	18%	
	2007	20%	44%	37%	
	Average	23%	46%	39%	

There is variation among the freeways as to the worst overall daily reliability rating, the worst PM peak rating, and the worst AM peak rating. I-84 West has the highest buffer index in the AM peak for all years, followed by Highway 26 East. I-405 South has the highest buffer index in the PM peak for all years, followed by Highway 217 South. The freeways with the highest daily reliability ratings for all years are I-84 West, Highway 26 East, and Highway 217 South. The following figures present this data in a more visual format.

Figure 8: Daily Buffer Index

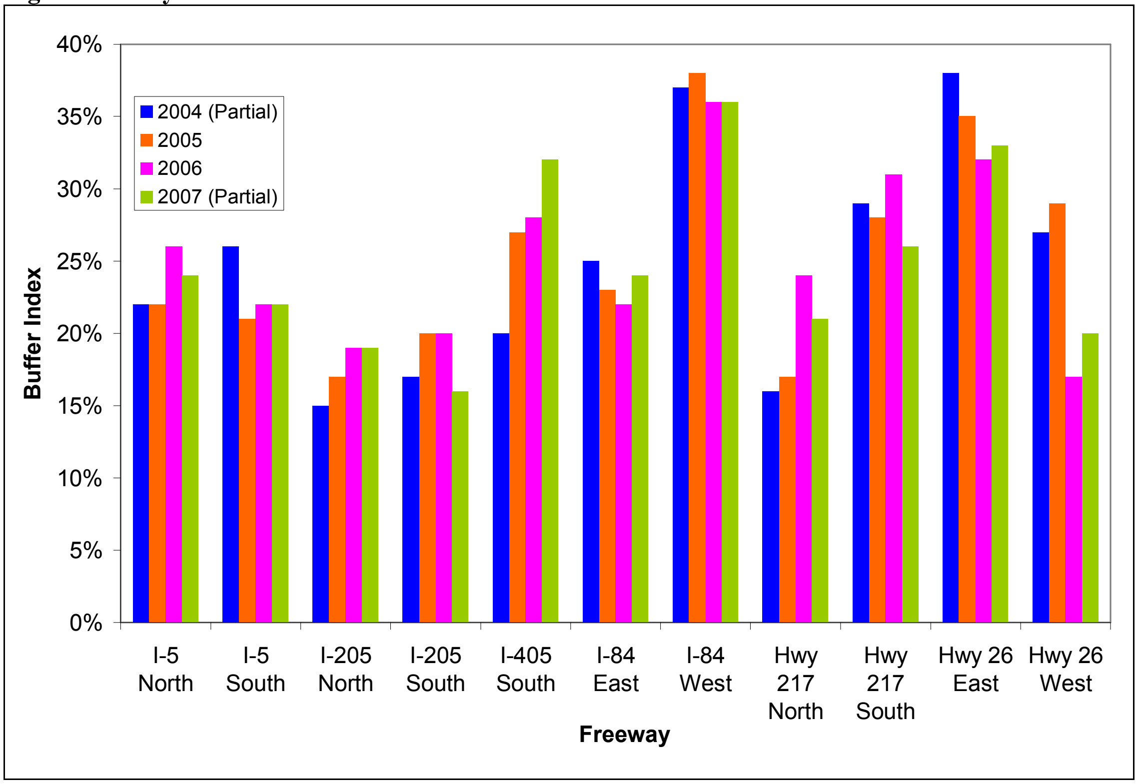


Figure 9: AM Peak Buffer Index

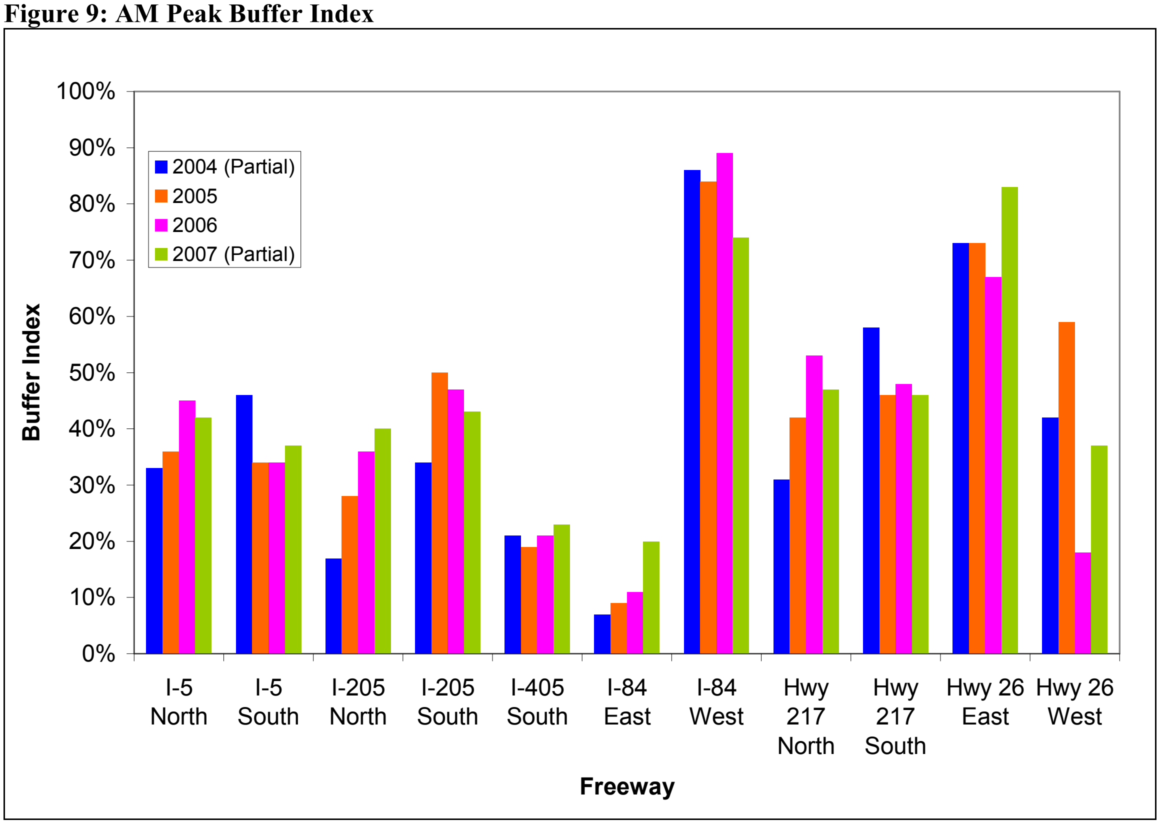
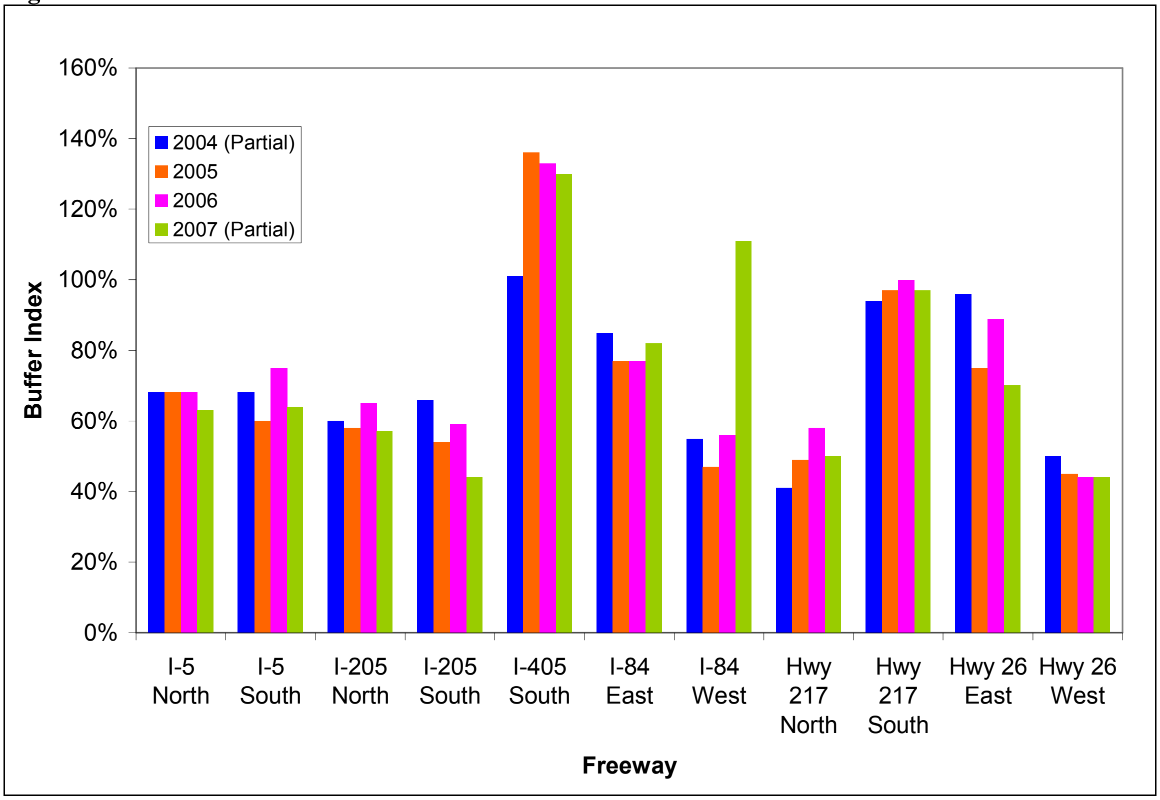


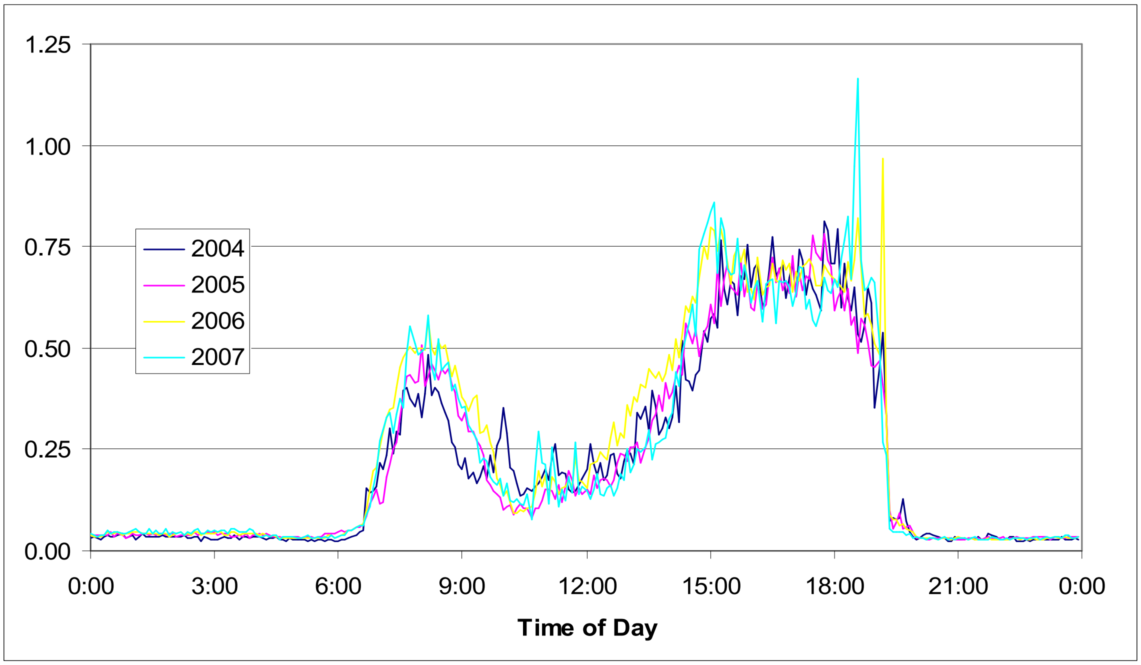
Figure 10: PM Peak Buffer Index



Analysis of Individual Freeway Segments

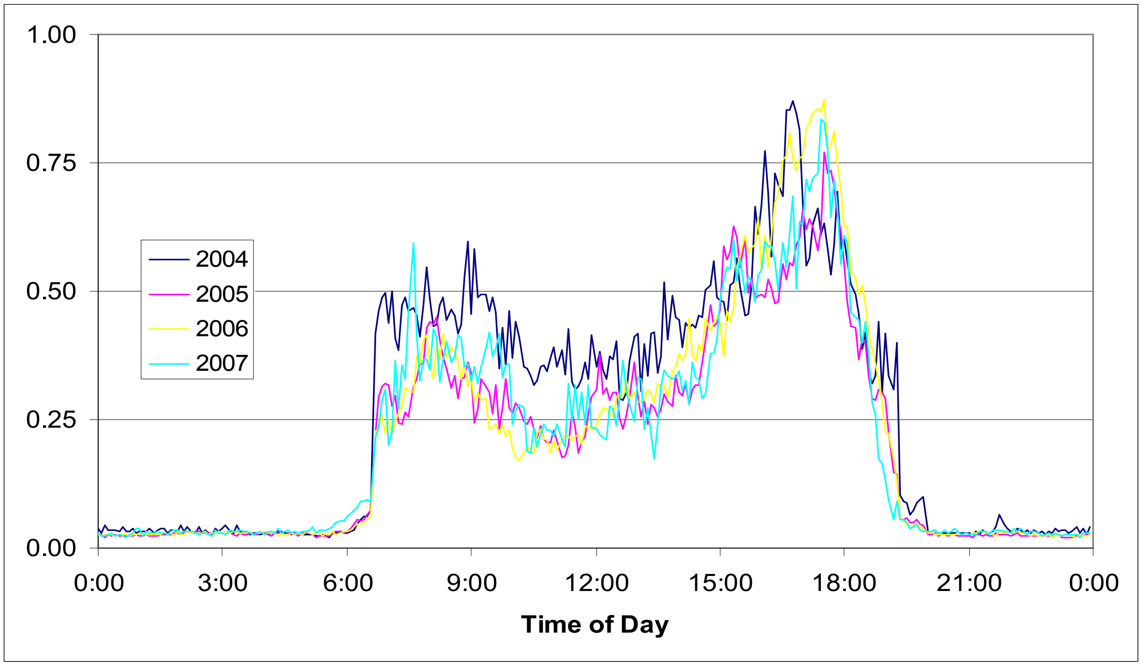
Figures 11 through 21 show the buffer index for all four years (averaged from monthly values) on each highway at 5-minute intervals.

Figure 11: I-5 North Buffer Index



As shown in Figure 11, I-5 North has a much higher buffer index in the PM peak than any other time of day. Both 2006 and 2007 indices have much higher spikes in the late PM peak than either 2004 or 2005. The values in the PM peak above 1.00 indicate times when travelers double the average travel time in order to travel at that hour. I-5 North appears relatively reliable during midday.

Figure 12: I-5 South Buffer Index



I-5 South, as evidenced by Figure 12, has a much lower buffer index in the PM peak than I-5 North and approximately the same buffer index in the AM peak as I-5 North. This figure also shows that there has not necessarily been an increase in the buffer index between 2004 and 2007.

Figure 13: I-205 North Buffer Index

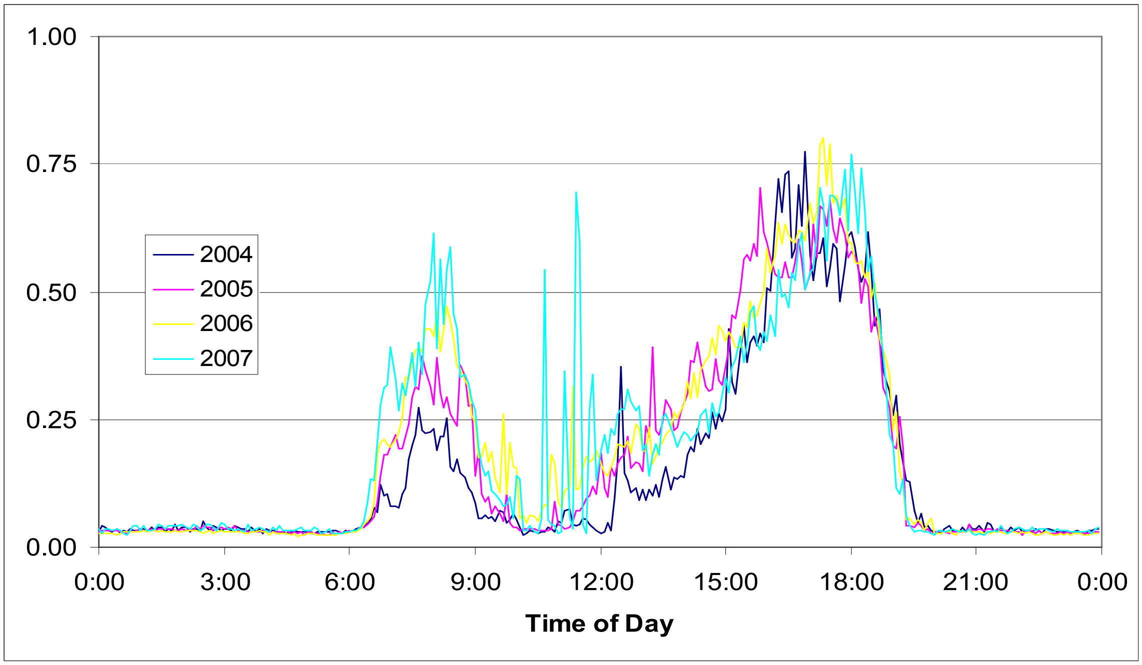
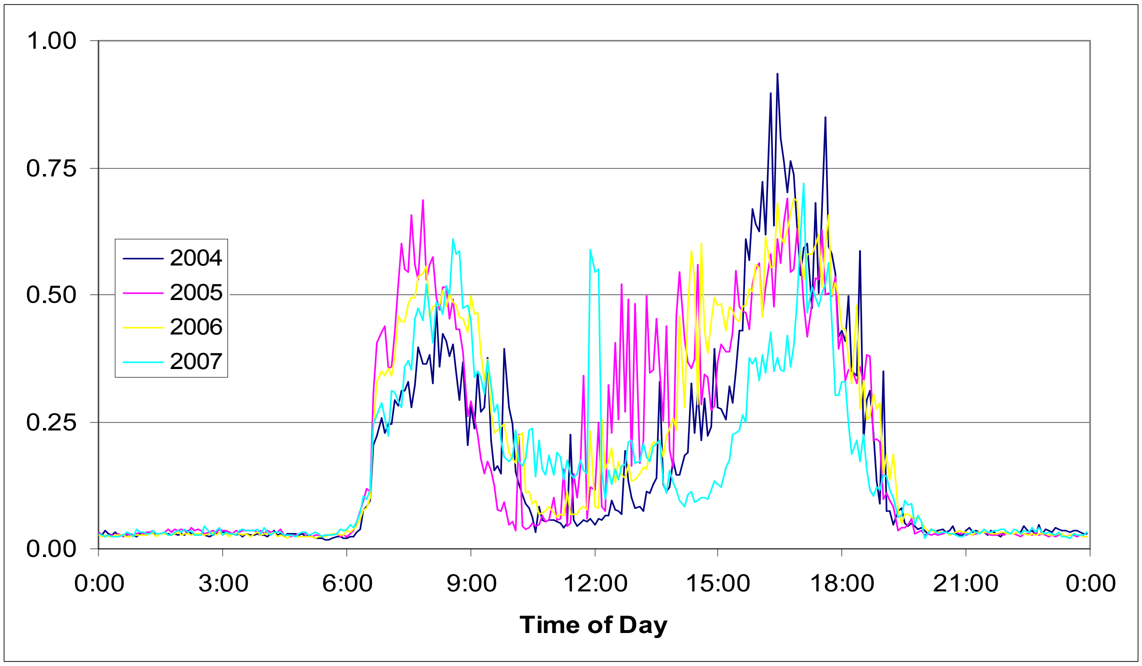


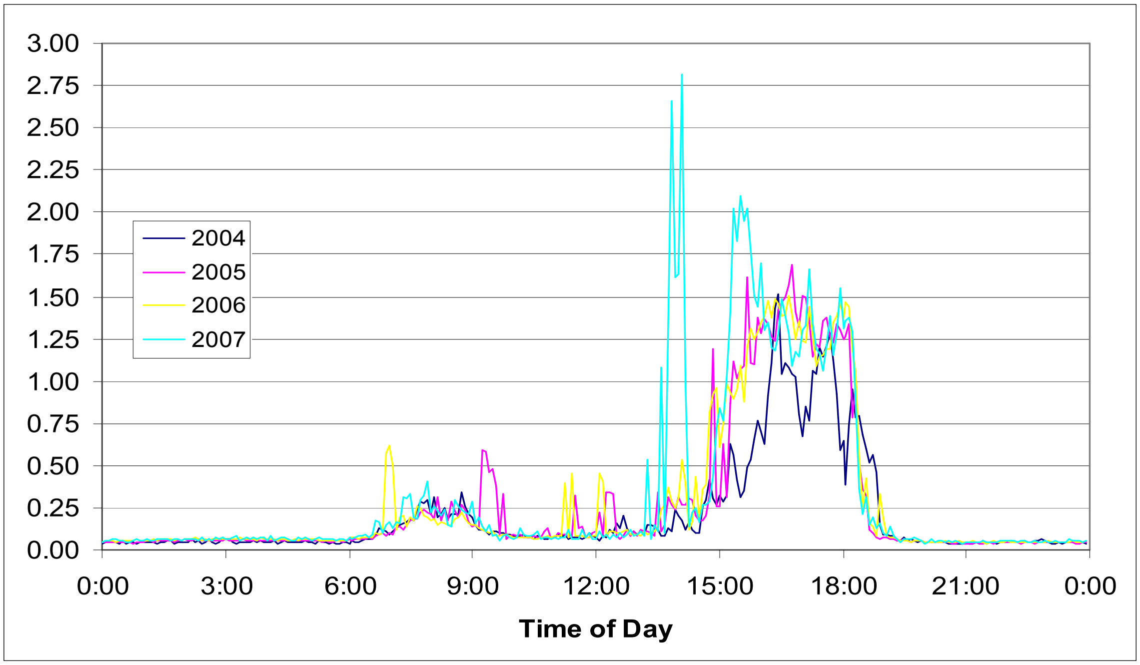
Figure 13 indicates that I-205 North has seen an increase in its buffer index in 2007, particularly in the AM peak and midday. This increase could have possibly been caused by a few major incidents or recurring construction during the same times of day. However, since this is only an average from January through April of 2007, it should be treated with caution. The PM peak buffer index is lower than both I-5 South and I-5 North.

Figure 14: I-205 South Buffer Index



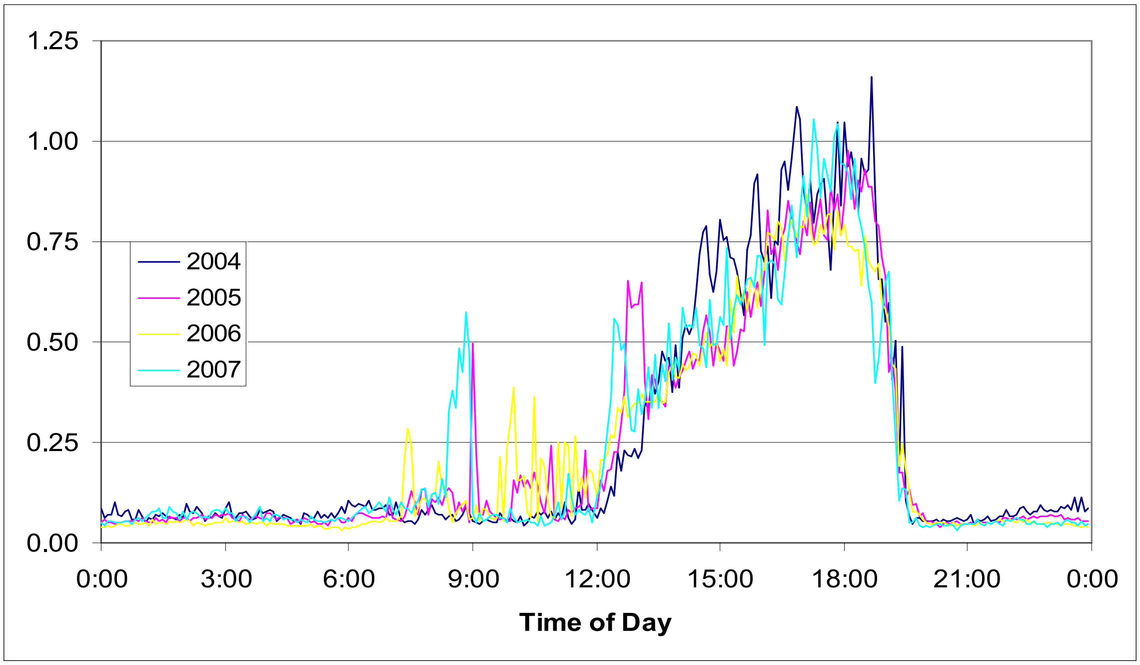
Interestingly, Figure 14 shows that the buffer indices for I-205 South have decreased since 2004 in the PM peak, and shifted slightly later in the AM peak. This could be symptomatic of a peak spreading phenomenon, or of commuters altering their commute times. This freeway shows a higher buffer index during the midday hours of 12 to 3 PM than other freeways, but the variation is mainly for 2005 data. In general, this freeway segment is more reliable than most others.

Figure 15: I-405 South Buffer Index



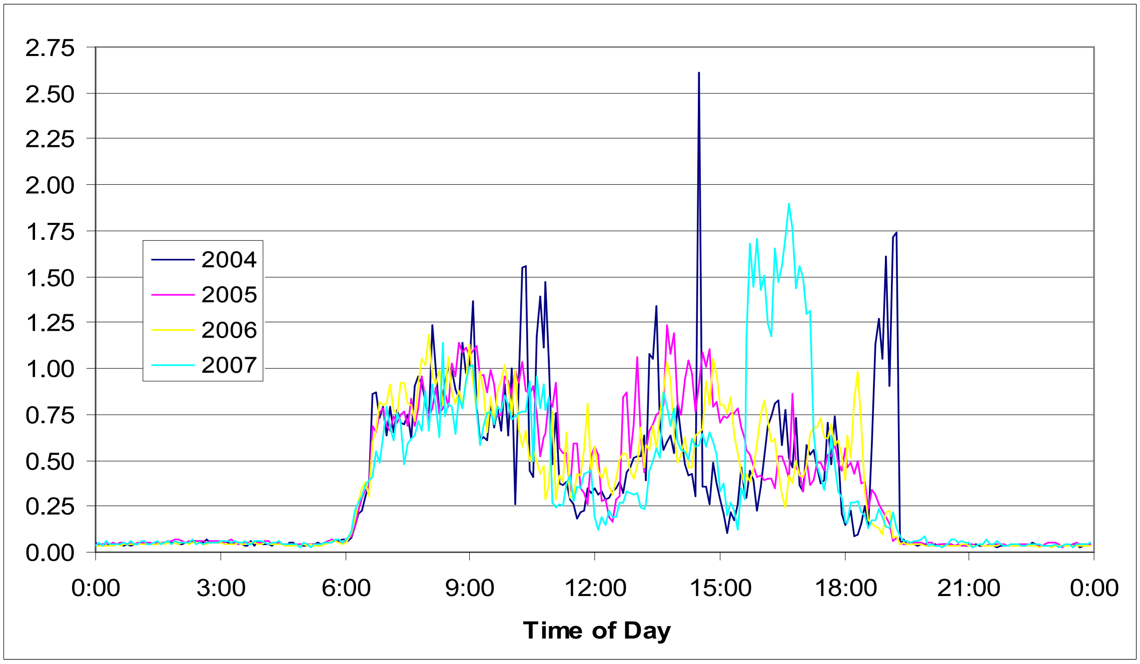
Although Figure 15 shows a very intense increase in the buffer index for I-405 South during midday in 2007, this data should be viewed with caution because the year is incomplete. Even disregarding the 2007 data, I-405 South has a very high buffer index of about 1.5 during the PM peak; although it should be noted that the relative shortness of this segment may exaggerate the effects of the index values given the low free flow travel times. This freeway segment has a relatively low buffer index in the AM peak and midday.

Figure 16: I-84 East Buffer Index



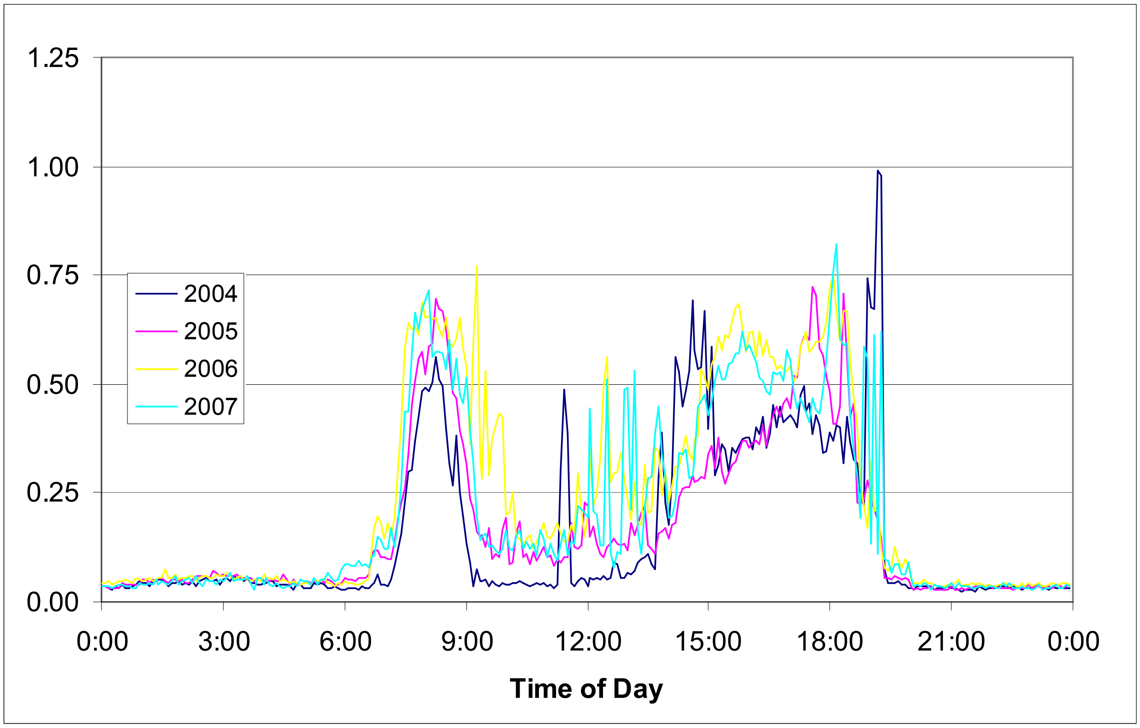
As shown in Figure 16, I-84 East has seen a large increase in the buffer index during the AM peak in 2007. The PM peak is higher relative to other freeways but has seen a decrease since 2004. Reliability on this freeway segment steadily worsens beginning at midday and continuing through the PM peak.

Figure 17: I-84 West Buffer Index



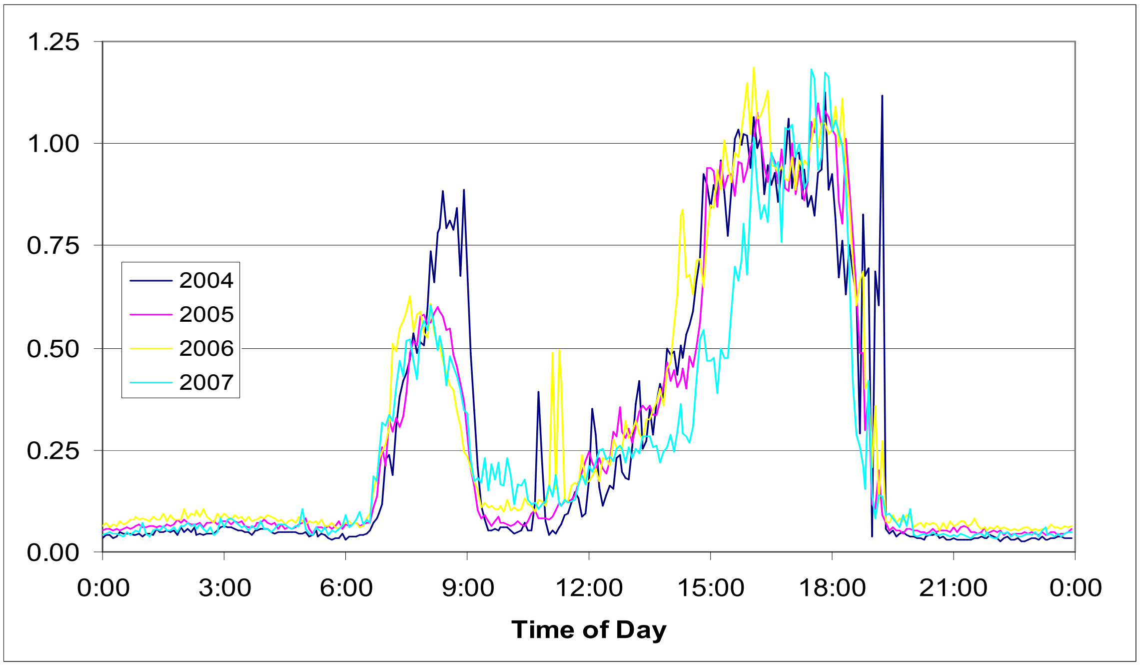
I-84 West has seen a large spike in the PM peak buffer index in 2007.There was a high buffer index during 2004 in the mid-day which has not repeated in subsequent years, which could indicate that the latter half of 2004 saw some construction on the freeway or had some major incidents.. Generally, the AM peak buffer index has decreased since 2004, but remains higher than other freeways.

Figure 18: Highway 217 North Buffer Index



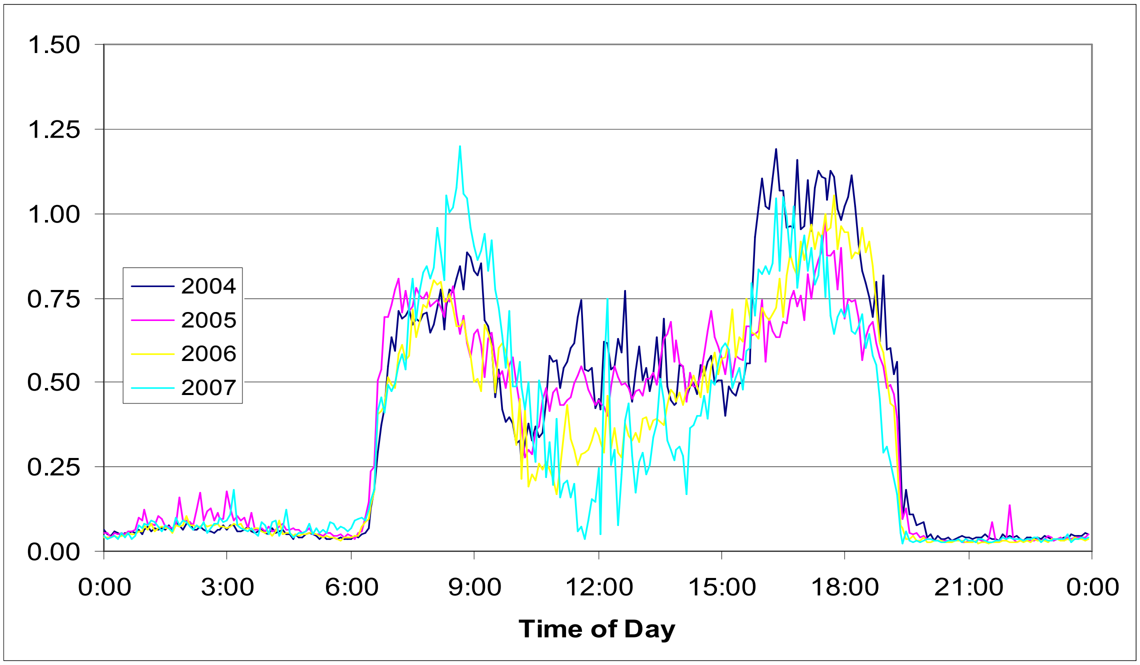
Highway 217 North, as evidenced by Figure 18, has a relatively low buffer index as compared to other freeways. The buffer indices are approximately equal in the AM and PM peak, and the PM peak index has decreased since 2004. Reliability in the midday has worsened in 2007, although is not as low as on other freeway segments.

Figure 19: Highway 217 South Buffer Index



Highway 217 South has a much higher PM peak buffer index than Highway 217 North. The AM peak index has decreased since 2004 although it still remains high. A high midday reliability rating in 2006 seems to have lessened in 2007. This freeway segment demonstrates a steady worsening of reliability ratings beginning in the midday and continuing through the PM peak.

Figure 20: Highway 26 East Buffer Index



As shown in Figure 20, Highway 26 East has a high buffer index in both the AM and PM peak hours. The AM peak has been much higher in 2007 than in previous years. The PM peak has decreased since 2004. This segment sees a distinct peak period in the AM and PM with a relatively good reliability rating midday--possibly reflecting the primary use of this freeway as a commuter route with low midday traffic volumes.

Figure 21: Highway 26 West Buffer Index

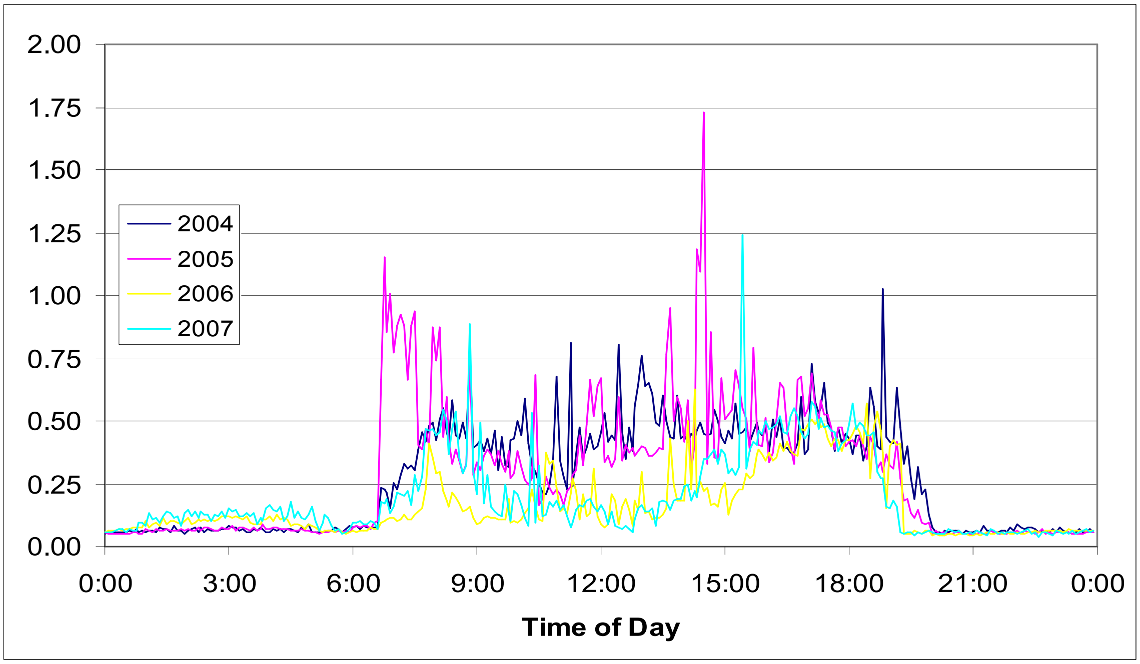
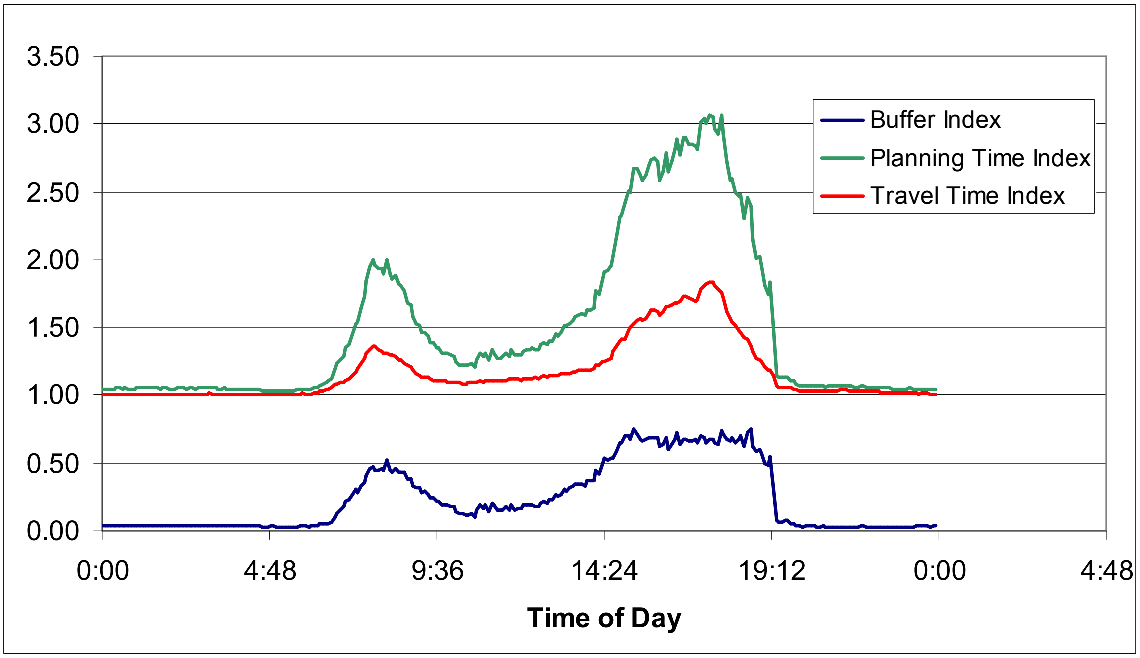


Figure 21 indicates that Highway 26 West has had a large variation in buffer indices according to year. 2005 shows a high spike in both AM and PM peak buffer indices. This freeway shows less distinction among the AM peak, midday, and PM peak, which may indicate this freeway is not simply used as a commuter route but may have major importance to businesses during working hours.

Comparison of Reliability Measures

The following figure illustrates the differences between the three travel time reliability indices approved by FHWA and discussed earlier in this paper: buffer index, travel time index, and planning time index.

Figure 22: Comparison of Reliability Measures on I-5 North



The figure above indicates that each index recommended by the FHWA would show approximately the same trends along a roadway, although the planning time index in particular seems to exaggerate the trends more than the buffer index or the travel time index. The buffer index is probably the most conservative measure to use because of its tendency to dilute the trends along a roadway.

Case Study Conclusions

All the freeway segments included in this analysis show higher buffer indices in the PM peak hours than in the AM peak. This could be because traffic volumes are generally higher in the PM peak or because the PM peak has experienced peak spreading to a greater degree than the AM peak. Many of them show very high spikes during specific years at specific times—which is possibly evidence of special circumstances such as construction during the same hour each day. Many freeways also showed a higher buffer index in 2007 than in previous years, but this may be due to the fact that only data from January through April of 2007 was included. Despite these variables, this data can still be used to prioritize freeway segments. The values indicate that it may be appropriate to create priorities based on time of day, particularly when choosing implementation levels for incident management programs. In Portland, priority should be given to I-84 West in the AM peak and I-405 South in the PM peak to improve reliability ratings.

Further research could help to present this data in a more comprehensive manner. Creating a standard of reliability and describing the number of minutes or hours per day that a freeway exceeds that standard could be another way to rate and understand travel time reliability comparisons.

Conclusions and Recommendations

Travel time reliability is an important measure of the health of a transportation system. Measuring travel time reliability can help to prioritize system improvements in a more nuanced way than simply by using the volume-to-capacity ratio. As shown by the Portland case study, reliability ratings can vary by time of day and by roadway.

Metropolitan Planning Organizations could incorporate travel time reliability into their regional transportation plans in three distinct ways:

First, improving and maintaining a standard of travel time reliability should be stated as a region-wide goal. Literature suggests that travelers are less concerned with the actual time that their trip takes than the consistency of that time (6). MPOs should recognize this by listing improvement of reliability ratings as a major goal of the RTP for all modes, along with safety, connectivity, mobility, and other important transportation goals. In doing so, they should establish goals for reliability according to time of day and roadway classification in the same way that MPOs and other agencies set LOS goals. As an example: Metro's 2004 RTP currently states that the region is committed to developing a transportation system that is based on efficient use of land, is safe, cost-effective, efficient, and supports regional land use goals. Metro should add the word "reliable" to its vision of the transportation system and should subsequently carry this through to their description of policies and evaluation strategies.

Second, MPOs need to evaluate their existing transportation systems for measures of travel time reliability. The case study of Portland exhibits how varied roadway segments can be in terms of travel time reliability and how important this variation is in determining priorities for needed improvements. If data is available, all regionally significant roadways should be evaluated and these measures should be used in conjunction with such measures as safety, volume-to-capacity ratios, and so forth.

Finally, MPOs should use the measures of travel time reliability to prioritize improvements into the system that could help to improve these ratings. These improvements could include: better incident response systems, road improvements at specific points to fix bottleneck points, or better traveler information. Once these improvements have been implemented, monitoring the reliability ratings will be crucial in assessing their effectiveness.

Travel time reliability is currently under-utilized in regional transportation planning. This paper has sought to prove its usefulness and its importance for determining where improvements need to be made. Further research could investigate how well specific improvements improve reliability ratings or how reliability improvements could also improve safety and overall travel time. More analysis could reveal how prioritizing roadways according to the V/C ratio would or would not result in a different set of recommendations for roadway improvements or the specific causes and solutions to reliability problems.

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