Transportation Impact Analysis Gets a Failing Grade When It Comes to Climate Change and Smart Growth

Ronald Milam, AICP
Principal
Fehr & Peers
2990 Lava Ridge Court, Suite 200
Roseville, CA 95661
r.milam@fehrandpeers.com

ABSTRACT

Transportation impact analysis performed to comply with environmental impact laws (i.e., the California Environmental Quality Act or the National Environmental Policy Act) often focuses on only one perspective about potential impacts. That perspective reflects how automobile drivers view the world because of general traffic engineering practices and how traffic operations are measured using level of service (LOS). With many communities more concerned about climate change, creating livable communities, and wanting to emphasize the use of transit, walking, and bicycling, the traditional traffic engineering approach to traffic operations analysis is not effective. Worse, it can result in smart growth projects being denied due to neighborhood opposition associated with worsening LOS and not understanding the other tradeoff benefits of infill and higher density development.

Instead of relying on vehicle LOS as the primary performance measure in transportation impact studies, agencies need to consider the tradeoffs between LOS and other important community values and other modes. This paper will present a new paradigm for transportation planning and impact analysis that reflects the inherent tradeoffs associated with vehicle travel, urban development form, and the treatment of other modes. The new paradigm will reflect a fundamental change in our current thresholds based analysis approach and it will demonstrate new analysis methodologies that focus on the following:

- improving person-capacity of our transportation system
- accurately describing transportation tradeoffs with other community values such as climate change, air pollution, or the ability to walk and bike
- demonstrating the effects of built environment changes on reducing vehicle travel

Case studies will be used to demonstrate these state of the art analysis methodologies.

INTRODUCTION

The concept of Level of Service (LOS) has been used by traffic and transportation engineers for over 50 years to describe operating conditions for automobile travel on existing or planned roadway facilities. Because it is primarily an automobile-oriented measure, many cities are struggling with how to weigh the trade-offs between providing efficient automobile travel and other community values. Some of the key values that can conflict with efficient automobile travel are listed below.

- Creating pleasant walking and bicycle environments
- Developing well utilized public transportation systems
- Reducing vehicle travel to minimize air pollution and green house gas emissions

This paper includes background on the existing definition and use of LOS and provides two case studies of innovative methods to evaluate transportation system changes that capture impacts for all users while also considering key tradeoffs between desired vehicle LOS and other community values such as those listed above.

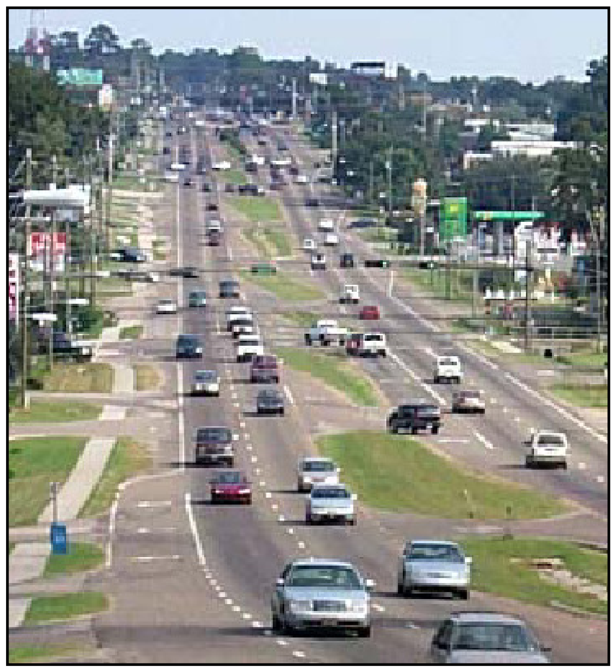
Before discussing the case studies, some background on LOS is needed. LOS is defined in the Highway Capacity Manual (Transportation Research Board, 2000) as follows:

> *Level of service (LOS) is a quality measure describing operational conditions within a traffic stream, generally in terms of such service measures as speed and travel time, freedom to maneuver, traffic interruptions, and comfort and convenience.*

Despite the above definition as a broad, qualitative measure of transportation conditions, LOS is, by far, most commonly determined by a quantitative measure, average delay per vehicle at intersections, usually for the weekday AM and PM peak hours. Delay is generally defined as the difference between the actual travel time a vehicle experiences and the time it would experience if there were no other vehicles or traffic control devices at the intersection.

The Highway Capacity Manual (HCM) specifies a methodology for estimation of average vehicular delay at intersections based on a combination of theoretical and empirical data. This methodology calls for use of a Peak Hour Factor, which extracts the peak 15-minute traffic volume from the hourly volume. This represents the 99^{th} percentile traffic volume on a typical weekday. Typical transportation operations analyses are conducted based on the HCM methodology, and are thus, based on the 99^{th} percentile, peak 15-minute, traffic volume on a weekday.

As defined by the Highway Capacity Manual, LOS is divided into six categories, ranging from LOS A to LOS F, just like a report card. LOS A represents free-flow travel, LOS B through D represent increasing density but primarily stable conditions, LOS E represents conditions at or near the capacity of the facility in question, and LOS F represents over-capacity, forced flow conditions. The unfortunate consequence of a grading system similar to school report cards is that members of the public, planners, decision-makers, and traffic engineers alike, often consciously or unconsciously, relate the two. In other words, there is a tendency to equate LOS D at an intersection with receiving a poor grade on a report card. While achieving a grade of A on a report card is the primary objective in school, achieving LOS A at an urban signalized intersection, for example, would likely be undesirable as public policy. At a minimum, it would be a questionable use of public funding especially viewing LOS through a strict economist's perspective. Considering that roadways are public infrastructure in most communities, an economist would likely consider LOS E as desirable under design year conditions. Achieving LOS E in the design year would indicate that the public infrastructure was operating at or near its design capacity while achieving LOS A or B (i.e., accommodating the 99th percentile traffic volume with little or no delays) would be a poor investment of scarce public funding.



Example of LOS C Conditions

Table 1, below, shows the LOS ranges defined by the HCM for signalized intersections. The identification of various LOS regimes was developed somewhat arbitrarily, as a way to assess driver perception of operating conditions. However, it is important to remember that driver perception varies from person to person, and is not divided into six discrete categories, but is more like a continuum. In other words, acceptable delays to one person may be unacceptable to another, and in terms of traffic operations, there is not a substantial quality of service difference between 19.9 seconds of delay per vehicle and 21.1 seconds of delay per vehicle, despite the fact that the two delay values represent two different LOS thresholds.

TABLE 1
SIGNALIZED INTERSECTION LOS CRITERIA

LOS	Average Control Delay (seconds/vehicle)	Description
A	≤ 10.0	Operations with very slight delay, with no approach phase fully utilized.
B	10.1 – 20.0	Operations with slight delay, with occasional full utilization of approach phase
C	20.1 - 35.0	Operations with moderate delay. Individual cycle failures begin to appear.
D	35.1 – 55.0	Operations with heavier, but frequently tolerable delay. Many vehicles stop and individual cycle failures are noticeable.
E	55.1 - 80.0	Operations with high delay, and frequent cycle failures. Long queues form upstream of intersection.
F	> 80.0	Operation with very high delays and congestion. Volumes vary widely depending on downstream queue conditions.
Source: *Highway Capacity Manual*, Transportation Research Board, 2000.		

Because "acceptable" amounts of delay and congestion can vary depending on a number of factors, the determination of what is acceptable and what is unacceptable is left up to local jurisdictions. Many rural communities with low traffic volumes desire to maintain LOS C or better operations, while many suburban areas define LOS D or better as acceptable conditions based on recommended thresholds contained in professional guidelines such as *A Policy On Geometric Design of Highways and Streets*, American Association of State Highway and Transportation Officials (AASHTO), 2004. On the other hand, many urban areas are beginning to describe traffic conditions in terms of number of hours at LOS F, because achieving LOS C or D during peak periods is not feasible especially considering past and present funding levels for new roadway construction.

CONSEQUENCES OF CURRENT PRACTICE

The current practice for use of LOS has three major consequences.

1. LOS ignores potential effects on non-automobile modes.

   Current practice based on the HCM does not provide a methodology to measure the intersection LOS for all users. In fact, the HCM procedures for measuring transit, bicycle, and pedestrian LOS rely on performance measures that are unique to the mode. For example, pedestrian LOS is based on pedestrian space (square feet/person). This particular measure has no relation to the delay caused at crossing intersections by pedestrians. Further, basing automobile LOS only on vehicle delay means that a vehicle with one occupant receives just as much influence as a vehicle with 50 occupants, such as a bus (although a bus will be recognized for being the equivalent of approximately two passenger cars due to its physical size). Therefore, an improvement that benefits 50 single-occupant vehicles would be shown to be 50 times more effective in reducing average vehicular delay than one that benefits a single bus with 50 occupants by the same amount.

2. LOS thresholds are established without recognizing the influence on air pollutants and green house gases.

   The exclusive use of delay-based LOS does not provide any information about the potential effect on air pollutant emissions or green house gas generation, which are now a major focus of impact analysis. This problem is exacerbated by the fact that many public agencies have established LOS thresholds without recognizing the important role speed plays in generating emissions. Green house gases and air pollutants are emitted from vehicles at different rates depending on the traveling speeds of the vehicles. Since a LOS threshold will influence roadway design and therefore the prevailing travel speeds of automobiles, it will also influence the amount of green house gases and air pollutants that are generated. The LOS threshold that generates the least amount of green house gases or air pollution may not be the same as that desired to minimize delay.

3. LOS thresholds are used to determine the size of roadways which influences land use form.

   Despite the embedded bias, automobile LOS is frequently used as the primary impact and design threshold for transportation facilities. Many jurisdictional LOS policies require that transportation facilities be designed to achieve a specific automobile LOS often without recognizing how the size of roadways influences land use form. Multi-lane roadways create physical barriers between land uses and result in large intersections that are not conducive to a quality walking and bicycling environment because they create longer distances between land uses and result in lower density development (refer to exhibit below).

Maintaining LOS C versus LOS E

This exhibit illustrates the consequences to pedestrian crossing distances and general infrastructure investments of widening an intersection to improve vehicle traffic operations from LOS E to C.

Another important land use form effect is related to the location of new land use development. Infill development is often accompanied by significant traffic mitigation because existing roadways are heavily utilized. Any additional trips are likely to trigger LOS impacts and the need for mitigation, which is often expensive due to constrained right-of-way. Suburban or rural development sites are more attractive because developers can avoid potential LOS-related impacts and the associated mitigation costs or the cost of mitigation is significantly less than an infill site. This incentive system encourages sprawl, reduces land use density, makes effective transit more difficult to provide, and reduces the attractiveness of walking and bicycling between destinations. An ironic side effect of attempts to avoid traffic congestion and delays through LOS policies is that infill development is often discouraged and people are forced to make longer trips, spending more time in their automobiles.

TRANSPARENCY AND COMMUNICATION

This paper is not meant to advocate elimination of the use of automobile LOS. Rather, it is meant to illustrate its limitations and the consequences of the current reliance upon automobile LOS as the primary measure of evaluation for transportation impacts and to highlight the lack of transparency among trade-off effects. Because transportation operations and impacts are typically boiled down to a simple letter grade, the consequences and trade-offs of various options are not adequately conveyed to decision-makers and the public.

For example, the social or environmental costs or impacts of roadway improvements are not often factored into decisions. Widening a roadway to maintain "acceptable" traffic flow may involve removing homes, trees, or open space in some cases; things on which a community may place a higher value than travel time. However, formal mechanisms don't generally exist in local policies or procedures to weigh these factors against each other, so the LOS threshold usually takes precedence. While most Comprehensive Plans and General Plans include statements supporting a certain automobile LOS, they also often support potentially competing values, such as reducing green house gases, maintaining bicycle and pedestrian-friendly environments, encouraging use of transit, maintaining open space, etc. The use of LOS should acknowledge the tradeoffs associated with other important community values when evaluating the transportation system.

One obstacle to effectively communicating the trade-offs between LOS and other criteria is that it has traditionally been difficult to communicate LOS to decision-makers and to the public. Most often, transportation studies provide tables with numbers representing average vehicular delay with an associated LOS letter grade for individual intersections. When making decisions, elected officials often rely on relative differences in LOS, but have a hard time conceptualizing how bad different levels of congestion actually are. For example, it is clear that LOS B is better than LOS D, but how bad is LOS D?

The good news is that the transportation planning industry has begun to develop tools that not only analyze transportation operations from a technical side, but also produce visual output (see example to the right) that enables both the public and decision-makers to visualize how things work. As microsimulation becomes more and more useful as a tool to answer increasingly complex technical questions, it also becomes easier to inform the public and decision-makers. For instance, it is much easier to explain how things will operate using video from microsimulation output than to tell someone that the average delay per vehicle is 28.3 seconds.

The new tools in the transportation industry can effectively convey the meaning of various LOS analyses and assess the transportation system as a whole. Better communication of LOS, in addition to recognition of the limitations and biases inherent in auto LOS as a performance measure will provide a more open and transparent discussion whereby planners, decision-makers, and the public can make better informed decisions regarding both development and infrastructure investment.

CASE STUDIES

The remainder of this paper is dedicated to describing two innovative approaches to use of LOS based on the transportation system user or customer focus, rather than a vehicle focus while also addressing tradeoffs with other community values.

San Francisco, California

Despite its famous and picturesque bridges, there are very few freeways within the City of San Francisco. The major north-south freeway along the US west coast, US Route 101, extends between Los Angeles, California, and Seattle, Washington. However, in the southern portion of San Francisco, the freeway portion of Route 101 becomes Interstate 80, and turns toward the east. Route 101 continues north through the City, along surface streets, until it reaches the Golden Gate Bridge and becomes a freeway facility again, traveling north through Marin County. Within San Francisco, the majority of Route 101 travels along Van Ness Avenue, a six-lane major arterial street that carries approximately 50,000 vehicles per day (*2005 Traffic Volumes on the California State Highway System*, California Department of Transportation, 2005).

In addition to high traffic volumes, Van Ness Avenue serves a high volume of transit. As part of a major long-term strategy to provide higher-capacity, enhanced transit service throughout the City, San Francisco has elected to pursue implementation of a Bus Rapid Transit (BRT) route along Van Ness Avenue (see exhibit to the right), which would remove either the center or curb lane of traffic in favor of dedicated right of way for buses. One potential alternative configuration is shown in the photo simulation to the right that was developed by the *San Francisco County Transportation Authority*.

Given the high levels of traffic on the street, removing a lane of traffic in each direction obviously has the potential to increase vehicular delays along the street. However, by providing more efficient service to transit vehicles, which carry many more people than cars, the overall person-delay may not be as drastically affected as the vehicle-delay. Using micro-simulation, we can model multiple modes in the same network, and capture the interaction between them. This provides the opportunity to assess impacts to different modes separately and to the transportation system as a whole. At the time this paper was written, the Van Ness Avenue BRT project was still in the technical analysis phases, but some performance measure results were available. Instead of focusing on vehicle LOS, the study compared person and vehicle delay as shown in the above sample results table.

Alternative	Person Delay (sec per person at avg intersection)	BRT Rider Delay (sec per person at avg intersection)	Vehicle Delay (sec per vehicle at avg intersection)
1, No Project 	20.8	20.9	19.3
2, Curb BRT Lanes 	19.1	10.6	19.3
3, Center-Side w/ two medians 	19.7	10.2	20.9

Source: Van Ness BRT Feasibility Study, Public Workshop, October 19, 2006, San Francisco County Transportation

Although the technical analysis was not yet final at the time this paper was written, the intent of the analysis was to evaluate performance of the transportation system from the perspective of multiple customers or users, as opposed to the more traditional vehicle-delay. As a result, while vehicle delays did increase for some alternatives, the overall person delay decreased and more people would be moved by public transit, which has the benefit of producing less air pollutants and green house gases on a per passenger basis.

Davis, California

The City of Davis, California, is a small, but rapidly growing suburban town of approximately 60,000 residents in California's Central Valley, approximately 20 miles west of Sacramento Sacramento (US Census, 2000). Davis is also home to one of ten campuses of the University of California (UC Davis), enrolling approximately 30,000 students (www.ucdavis.edu). Because of its relatively high student population, its favorable weather, and relatively flat topography, there is a great deal of bicycle and pedestrian activity throughout the town.

A transportation impact analysis conducted by the author's consulting firm for a new campus building recommended improvements at one nearby intersection. However, because of the high pedestrian and bicycle use of this intersection, UC Davis planners wanted intersection improvements that would improve pedestrian and bicycle accessibility while minimizing conflicts with vehicles. To that end, the impact analysis identified five alternatives for analysis with the intent of selecting a preferred set of improvements that would meet all the project's objectives.

The five alternatives analyzed are listed below.

- Alternative 1: Provide all pedestrian/bicycle signal phase
- Alternative 2: Provide exclusive phase only for southbound (SB) and westbound (WB) cyclists who travel on a Class I bicycle bath. Cyclists traveling on other approaches would travel with vehicles using the regular vehicle signal phase.
- Alternative 3: Traditional design (no exclusive bicycle and pedestrian phases)
- Alternative 4: Provide five-second "head-start" phase for SB and WB cyclists traveling on Class I bicycle path.
- Alternative 5: Provide grade-separated bicycle crossing connecting SB and WB Class I bicycle paths

For this study, the VISSIM micro-simulation software was used to develop a model of the study intersection and all the modes that use the intersection.[1] VISSIM was selected for this study because of its ability to isolate and model multiple modes. This is not the only software package available for this type of analysis, but understanding the project objectives early was essential in selecting a tool that was capable of demonstrating the effect of intersection changes on all the travel modes. This software also has the ability to estimate air pollutant emissions as a standard output.

The VISSIM model was constructed by drawing the roadway network using the aerial photographs as a background. The number of lanes, configuration of turn pockets, and location of lane additions and drops were confirmed by field observations. Additional detail was incorporated into the VISSIM network (posted speed limits, grades, etc.) to better reflect observed field conditions. Traffic signal operation (i.e., cycle lengths, phasing, and timing plans) for intersections were specified. Driver behavior parameters (i.e., yielding right-of-way at intersections, saturation flow rates, and driver aggressiveness) were calibrated based on field observations. The distribution of vehicle types was also calibrated to local conditions so that the percentage of trucks and high-occupancy vehicles (HOVs) match the traffic counts.

[1] VISSIM is a microscopic simulation model and a component of the PTV vision® suite offered by PTV America, Inc. located in Corvallis, Oregon.

Since micro-simulation models like VISSIM rely on the random arrival of vehicles, multiple runs are needed to provide a reasonable level of statistical accuracy and validity. Therefore, the results of ten separate runs (each using a different random seed number) were averaged to determine the final results.

Using the VISSIM model, the average delay was calculated for each mode and averaged for each alternative based on existing traffic, bicycle, and pedestrian counts. The overall results are shown in Table 2.

TABLE 2
HUTCHISON DRIVE/LA RUE ROAD INTERSECTION –
YEAR 2005 PM PEAK HOUR DELAY FOR ALL TRAVEL MODES

	Travel Mode (1)				
	Vehicles	Buses	Pedestrians	Bicycles	Overall
Option	Average Delay – LOS	Average Delay – LOS	Average Delay	Average Delay	Average Delay
1 - Bike/Pedestrian Phase	44.2 – D	47.1 – D	46.6	42.8	44.2
2 - Bike/Pedestrian Phase for Path Only	45.0 – D	47.7 – D	46.7	48.3	45.3
3 - Traditional Design (Current Configuration)	30.0 – C	29.6 – C	42.7	47.5	31.4
4 – Head Start Phase for Bike Path	40.5 – D	32.5 – C	24.4	34.7	39.6
5 – Grade Separated Crossing	28.7 – C	29.8 – C	64.2	15.1	28.1

Notes:
(1) The *Highway Capacity Manual* does not assign an LOS for pedestrians and bicyclists based on average delays. Delays were reported for comparison purposes only.
(2) The increase in pedestrian delay is associated with a reduction in pedestrians that are now using the grade separated crossing resulting in a higher average delay per pedestrian for remaining crossings on other approaches.

The operational analysis indicated that providing the grade separated crossing in Alternative 5 would result in the lowest average delay for all modes of travel, while maintaining a traditional design would provide the second-lowest amount of delay (see Appendix A for technical calculations for these two alternatives). Alternative 5 also resulted in a vehicle LOS of C, which is better than the minimum LOS D threshold required by UC Davis. Providing an exclusive bicycle phase for the bicycle paths only would result in the highest overall delay, averaged for all modes. An illustration of Alternative 5 is shown below alongside the delay and LOS results.

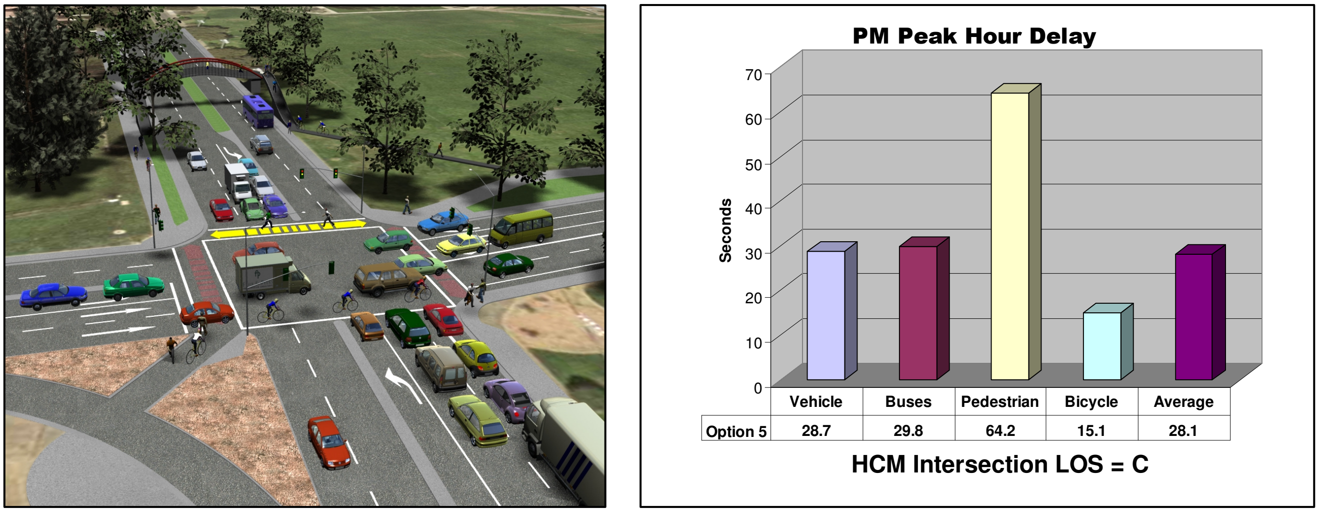


Illustration of Alternative 5 (bicycle/pedestrian bridge) and analysis by mode

Alternative 5 was particularly effective in this case because the new grade separation provided a shorter distance connection between student housing on the west side of La Rue Road, which runs north-south in the photo simulation above) and the campus on the east side. The grade-separation could also be located to avoid existing trees and utilities. In addition to the delay effects, it was noted that investments in bicycle and pedestrian facilities can also lead to greater use of these modes in the future, which can help reduce vehicle travel and its associated impacts on air pollution and green house gas emissions.

This information, along with other factors, such as impacts to air pollution, cost and right of way availability, were used by UC Davis to select a preferred alternative with a full understanding of the trade-offs for each mode associated with each alternative. In addition, the visual animation produced by the simulation software was extremely helpful in illustrating the alternatives and the operations of various modes to decision-makers and members of the public.

The additional delay information and visual simulations did not come without additional time, effort, and cost compared to conventional analysis as documented in the following list.

- Traffic count costs were approximately 50 percent higher because bicycles and pedestrians had to be counted.
- Ridership data had to be collected from the transit operator (not a normal input for an intersection analysis).

- Simulation model set up and operation took approximately 100 percent more person hours compared to conventional analysis using programs such as the Highway Capacity Software (HCS) or similar program.

This increase in cost was offset by analysis results that provided a higher level of confidence in the potential outcomes and a more complete picture of all project effects.

CONCLUSION

The strict use of automobile LOS as a design threshold and a transportation impact criterion contains a number of hidden biases that passively encourage urban sprawl, increase dependence on the automobile, and create physical environments that are not conducive to walking and bicycling. Many cities that have adopted policies in support of a successful transit system and a pleasant walking and bicycling environment find it difficult to implement projects consistent with these policies because of their impacts to auto LOS. To better understand the relationship between community values and desired traffic operations, the following new approaches, tools, and performance measures are needed to represent the perspective of multiple transportation system users.

- Tradeoff Approach - At a minimum, the approach to transportation planning or impact studies should clearly acknowledge the trade offs between a community's desired vehicle LOS and other important community values.

- Use Simulation Tools - Simulation tools are now available that can isolate the effects (i.e., delays) to all transportation system users whether they travel by vehicle, walk, or take transit. The animation capabilities of these tools are particularly effectively at communicating these effects to non-technical audiences.

- Focus on Moving People – The focus of transportation analysis should be on moving people and not solely on moving vehicles. A vehicle LOS ignores some users and can bias a transportation analysis because of what it doesn't tell us about how transportation system changes will affect other users. Using simulation tools, performance can be measured in terms of number of persons moved or delayed.

REFERENCES

Documents

Hass-Klau, C. (1990) *The Pedestrian and City Traffic*, Belhaven Press, London.

Highway Capacity Manual, Transportation Research Board, 2000, Washington, D.C.

A Policy On Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, 2004.

2005 Traffic Volumes on the California State Highway System, California Department of Transportation, 2005

US Census, 2000

Presentations

Van Ness BRT Feasibility Study, Public Workshop, October 19, 2006, San Francisco County Transportation Authority.

Websites

www.ucdavis.edu