Methodology for Defining Rational

&

Defensible Highway Occupancy Charges

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ABSTRACT

Occupancy of travel lanes during construction impact traffic flow and generate delays on the users. Thus, occupancy of travel lanes imposes costs on the traveling public due to traffic slowdowns or even shutdowns. At rush-hour these user costs come to a peak. Since closure of travel lanes are scheduled events, they can take place at times when such effects are minimized.

Objective of this study was to develop a methodology for defining rational and defensible lane occupancy charges that would eventually minimize the impact from traffic lane closure. The project research team examined heavily traveled locations in the NJ region to examine traffic and construction patterns to be used in the analysis and definition of the general occupancy charge methodology. Information regarding traffic flow with respect to time of day, season, AADT, highway characteristics, etc. were reviewed in this examination. The project considered both economic and simulation analysis for examining the impact on user cost and construction operations due to different patterns of lane closure.

KEY WORDS: Lane Occupancy Charges, Work Zone, Traffic Delays, User Cost, Highway

INTRODUCTION

During recent years innovative bidding and contracts have been used (1,2,3,4). To date few states are using lane occupancy charges. Generally, each price bid under this scenario consist of two parts: the first part involves the activities and cost for the work to be performed; the second part describes the number of days to complete the project and the cost associated for the lane rental amount based on the daily rental rates.

The lane-by-lane rental method is assessed only when the contractor closes a portion of the roadway (2). The rental charge is based on the number, duration and configuration of lanes closed (3). For example, the fee for having one lane and one shoulder closed would be less than that for having two lanes closed. In addition, higher rental amounts can be assessed for peak periods of the day. Also lane rental may incorporate different charges depending on the time of day lane closure occurs since it affects different traffic levels.

A critical factor in defining rational and defensible lane rental charges is the determination of appropriate rental dollar amount. In several cases, and as suggested from several survey responses, It is often concluded that appropriate rental charges must be determined on a project-by-project and/or case-by-case scenario. The rental charges should be related to the impact on road-user costs in function of the anticipated delays, accidents, and revenue loss. Lane rental charges should eventually include increased construction and maintenance costs and traffic control costs due to lane occupancy. The evaluation of road user costs have been documented in several references (5,6,7,8,9,10). In most of the cases lane rental charges are based only on travel delays since several of the remaining parameters are variable in time, are difficult and time consuming to measure and quantify.

SURVEY ON LANE OCCUPANCY CHARGES

A national survey was undertaken to examine the experience and use of lane occupancy charges in the 50 US states. The survey included questions on the definition and methodologies used in defining lane occupancy charges and the type of economic and traffic analysis used. From the 50 States it seems that only a few are using or planning to use this approach in the near future. The responses indicate that only travel delays are used for defining occupancy charges, in many cases occupancy charges were defined on a project by project basis, and typically user cost values used were from the "red book". In many cases the benefits of using occupancy charges were associated with the reduced construction time for project completion. Table 1 presents a summary of the analysis used in defining lane charges by specific States.

METHODOLOGY

The objective of the study was to address the need in developing appropriate guidelines for lane charges that would minimize the closure of traffic lanes. The developed guidelines considered the impact on traffic and road users, depending on the characteristics of the projects. The guidelines identify lane occupancy charges which are suitable to reduce closure of lanes to traffic. The methodology provides the general lane closure guidelines that can be used on a specific project and with respect to the specific project characteristics related to the AADT during the time of day, season, and type of highway/ lane closure. These guidelines were defined based on the examination of the effects of lane closures on traffic flow, and were defined based on project types and characteristics identified by NJDOT engineers.

The methodology is based on i) the estimation of traffic delay using traffic simulation analysis; and ii) calculation of total delay cost using average earning values. The delay, and thus cost, is a function of time of day, day of the week, number of lanes closed, traffic volumes over time, road characteristics and grade, average user cost per time delay, etc.

Estimation of moving and queuing delays

Due to lane closures in work zones motorist experience travel delays associated with reduced travel speed due to limited roadway clearance, narrowed lanes, and rubbernecking factors. Moving delay can be estimated from the difference between average travel times under normal conditions and work zone conditions. Moving delay $t_M(i)$, (min), is obtained in function of the relationship between work zone capacity C_w, (vph), inflow $Q(i)$, (vph) during $t_p(i)$, (min), duration of time period i $t_p(i)$, (hr), and queue length accumulated from the previous time period $q(i)$, in minutes, (11, 12, 13, 14, 15, 16).

Two main methods have been developed for analyzing freeway queuing delay. These include deterministic queuing models (11, 12, 13, 14) and shock wave models (15,16). The deterministic queuing models are using as inputs the demand volume Q, freeway capacity C, work zone capacity C_w, and work zone duration t_1. The main limitations of the methods using deterministic models for estimating work zone congestion include:

(1) Some methods used peak hour factors instead of actual traffic counts to estimate traffic demand during work zone period.

(2) Data on traffic counts and work zone times are often not collected simultaneously.

(3) The speeds used to estimate work zone delay are not the actual speeds through the work zone queues.

(4) An assumption that the initial demand level is smaller than freeway capacity is not valid under peak conditions.

In the case of shock wave model queuing delay is estimated by assuming that (1) the traffic flow is analogous to fluid flow, and (2) the shock wave speed propagates linearly. The shock wave speed is approximated based on traffic density since it is difficult to measure from flow density relations.

In order to avoid simulating huge number of situations (combinations of demand flow rates, traffic composition, geometric conditions, and work zone length and duration), a method integrating the concept of deterministic queuing model and simulation was developed (17) for estimating the queuing delay caused by lane closures (based on work zone configurations) on freeways. The traffic flow distribution over time and work zone capacity are the major inputs for this method and the queuing delay in each time period is calculated based on the queue length accumulated from the previous time period. If the queue length is zero at time period i, the queuing delay $T_Q(i)$ is purely incurred by flow $Q(i)$ during $t_p(i)$, and can be obtained using the following equation:

$$T_Q(i) = Q(i)t_a t_p(i) \quad (1)$$

where t_a represents the average queuing delay (veh-min). When there is a queue accumulating from the previous time periods ($q(i) > 0$), the queuing delay is determined based on the flow $Q(i)$ during $t_p(i)$, the work zone capacity C_w, and the duration to discharge $q(i)$.

In several studies, CORSIM (CORidor SIMulator, a microscopic simulation model developed by Federal Highway Administration) has been used successfully for freeway operational analysis, such as velocity and capacity studies (17,18,19). Thus this model was used for traffic simulation analysis and capacity evaluation in alternative work zone scenarios. Further details on the methodology developed under this study are reported by Goulias et al, (20).

The accuracy of the proposed methodology was evaluated by comparing the difference among the estimated queue and total delays obtained from CORSIM, the proposed method and a deterministic queuing model, for various work zone configurations. The results shown in Table 2 indicated that the queue delay obtained from the proposed method is close to that observed from CORSIM. The deterministic queuing model significantly underestimates the total queuing delay, since the delay caused by shock wave and acceleration/deceleration, while vehicles are approaching the work zone, is not taken into consideration.

An example case is included herein in order to present the results obtained using the methodology developed in the study. In this case example the following conditions were considered.

Number of Lanes per direction = 2
Number of lane closed = 1
Work zone Length = .5 mile
Work zone capacity = 1450 pcph
Duration of work = 10 hours
Average approaching speed = 70 mph
Average work zone speed = 50 mph
Flow rates over 10 hours are shown in Table 3.
Truck = 0%, 5%, 10%, 15%, and 20%
Grade = 0%

The work zone in this case was scheduled to finish at 5:00 AM; however all lanes of this work zone were opened to the public until 3:00 PM. Details of moving and queuing delays were determined. And queuing delays with 0, 5, 10, 15, and 20% truck were evaluated. The total delay includes the queuing and moving delays caused by trucks and cars and is summarized in Table 4 and show in Figure 1. Queuing delays at all time periods with $V/C_w \geq 1$ for 0, 5, 10, 15, and 20 % trucks were examined. Two examples are shown in Figures 2 and 3, for 0% and 20%trucks respectively.

Calculation of Delay Cost

Once the traffic delay for the specific work zone situation is determined the total delay cost is evaluated in function of the delay time per vehicle multiplied by the average earning per minute per passenger and the number of vehicles:

$$DC = DT/V \times AHE/60 \times n \qquad (2)$$

Where, DC is the delay cost ($); DT is the delay time (min); V is the vehicle considered; AHE is the average hourly earnings; and n is the number of vehicles. A more detailed method maybe used which distinguishes between income groups. In such a case the average income per group and its weight should be used in modifying the above equation. In both cases, the delay is a function of time of day, day of the week, number of lanes closed, road characteristics and grade, etc.

For the 2-lane road case presented one can estimate the cost of delay by using the total delays, Table 4, and the value of time as percent of wage rate at the range of $10.5 to $15 an hour. As it can be seen from Table 5, without trucks in the system the cost ranges between $4,719 and $6,741 an hour. At the present time with $6 an hour charges, the lane closing charges would have been $2,696.58, which is only 57 percent of the calculated minimum. The cost is much larger with trucks in the system. For example, with 10% trucks and considering an opportunity cost per truck of $50 an hour, and cost for other type of vehicles of $15 an hour, the total delay cost can reach $16,014.84. This turns out to be 3.4 times larger than the smaller amount mentioned before, and almost 6 times larger than the present practice.

CONCLUSIONS & RECOMMENDATIONS

The methodology defined in this research considers the traffic characteristics of specific work zone scenarios and highway characteristics in order to estimate traffic delays for alternative scenarios. Specifically, queuing delay, using CORSIM, was estimated by combining the simulation results and a deterministic model, while a mathematical model was developed for estimating moving delay. Lane occupancy charges were then defined using the delay as a function of: time of day, day of the week, number of lanes closed, traffic volumes over time, road characteristics and grade, average user cost per time delay, etc. In addition the methodology for defining lane occupancy charges considers traffic characteristics and demographics of road users income. Alternatively, average values of income may be considered for simplifying the analysis. As it appears from the illustrative example, the methodology is sensitive to the percentage of trucks using the roadway since delays on the moving of goods will provide significant impact on both traffic and revenue loss.

As suggested in this research, in order to determine the lane occupancy charges accurately one needs to survey the road users in order to determine: the mix of users between trucks, buses and cars; the income groups of each user category; the congestion level per time of day; the vehicle hour delay per hour of the day. Alternatively a weighted average of users and their value of time may be used to simplify the calculations. It is also recommended to develop and use a more dynamic method related to the "standard mileage approach," considering eventually the federal government travel allowance rate updated periodically, rather than using average hourly values, such as the one in the red book that have not been updated for several years.

Further development in the traffic analysis of this work is to develop an enhanced delay estimation model for analyzing traffic impacts and producing travel time information under various situations, such as geometric conditions (i.e., ramp junctions, interchanges, curvature radius, and grade section) and weather conditions (i.e., fog, rain, snow and ice). The current model, while estimating delays, provides conservative results; nevertheless, it represents a good starting point in the search for a better delay estimation model. Furthermore, the methodology developed and presented herein is flexible enough to consider any model and eventual assumptions that NJDOT engineers feel to better represent the specific conditions where lane occupancy charges are applied.

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TABLE 1 Summary of State Responses

	Lane Charge Analysis Based On	
States Using/ Plan to use Lane Charges	Economic Analysis	Traffic Analysis/Simulation
Oregon	User Cost (red book*)	Yes
Arkansas	User Cost (red book*)	Yes (traffic counts)
Wisconsin	User Cost /QUEWZ	Yes (traffic counts & simulation)
Indiana	User Cost /QUEWZ	Yes (traffic counts)
Colorado	User Cost /QUEWZ	Yes (traffic counts & simulation)

*1977 AASHTO publication “A manual on user benefit analysis of highway and bus transit improvements”

TABLE 2 Estimated Delays from Different Methods

Methods	Total Delay (veh-hr)		
	Case 1	Case 2	Case 3
Proposed Model	1831.46	4283.68	3881.63
Simulation Model	1810.18	4451.6	3707.83
Deterministic Model	1450	3200	2620

TABLE 3 Flow Rates (vph) Over Time

Time Period	Duration (hr)	Demand Flow Rate (vph)
1	5:00 –6:00	800
2	6:00-7:00	1000
3	7:00-8:00	1200
4	8:00-9:00	1600
5	9:00-10:00	1500
6	10:00-11:00	1200
7	11:00-12:00	1000
8	12:00-13:00	700
9	13:00-14:00	700
10	14:00-15:00	700

TABLE 4 Total, Queuing and Moving Delays

Percentage Truck	Total Delay (veh-hr)	Queuing Delay		Moving Delay	
		Truck	Car	Truck	Car
0	449.43	0	419.72	0	29.71
5	646.25	30.827	585.713	1.4855	28.2245
10	865.67	83.596	752.364	2.971	26.739
15	1122.42	163.906	928.8	4.4565	25.2535
20	1413.99	276.856	1107.424	5.942	23.768

TABLE 5 Total Delay Costs

% Truck	Total Delay (veh-hr)	Cost per hour @		
		$6.00*	$10.50	$15.00
0	449.43	2696.58	4719.02	6741.45
5	646.25	3877.50	8061.97	10824.69
10	865.67	5194.02	12508.93	16014.90
15	1122.42	6734.52	18435.69	22728.93
20	1413.99	8483.94	26017.40	31107.70

*The $6 an hour is used across the board.

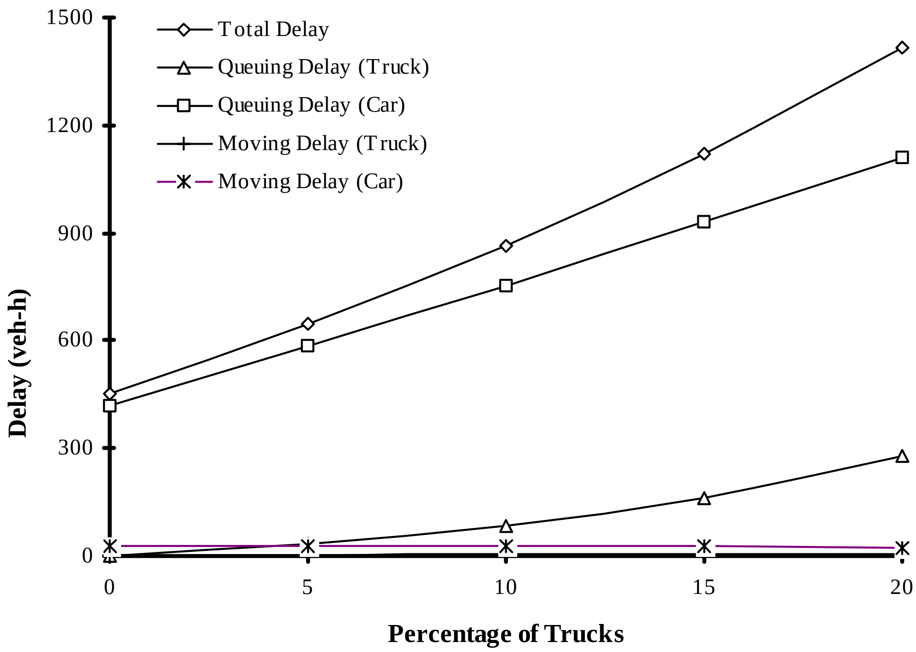

FIGURE 1 Delay vs. truck percentage.

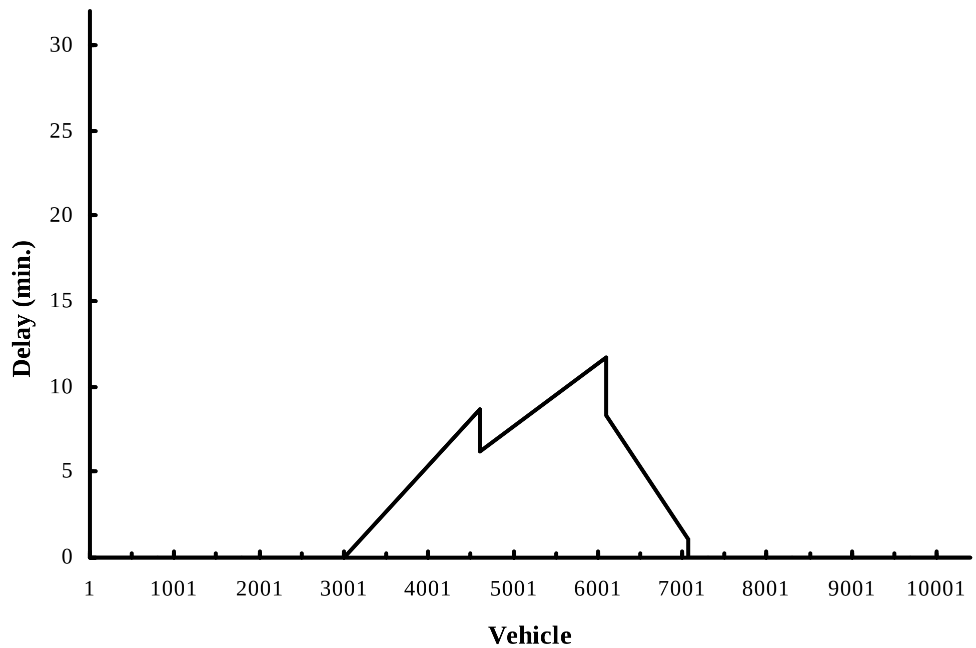

FIGURE 2 Vehicle arrival vs. queue delay (0% truck).

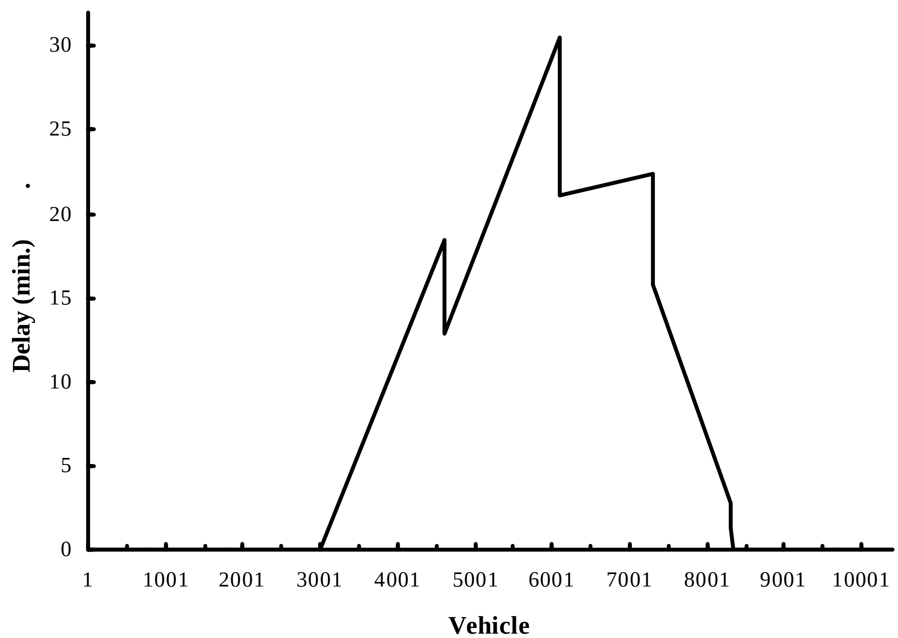

FIGURE 3 Vehicle arrival vs. queue delay (20% truck).