TRAFFIC DEMAND DYNAMICS DURING URBAN FREEWAY SHORT-TERM LANE CLOSURES

Xiao Qin, PhD, PE*
Assistant Professor
Department of Civil and Environmental Engineering
South Dakota State University
Brookings, SD 57007
Email: Xiao.Qin@sdstate.edu

Kelvin R. Santiago-Chaparro
Research Assistant
Department Civil and Environmental Engineering
University of Wisconsin-Madison
Madison, WI 53706
Phone (787)438-4076
Email: ksantiago@wisc.edu

David A. Noyce, Ph.D., P.E.
Associate Professor
Department of Civil and Environmental Engineering
University of Wisconsin-Madison
1204 Engineering Hall
1415 Engineering Drive
Madison, WI 53706
Phone – (608) 265-1882
Email: Noyce@engr.wisc.edu

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*: Corresponding Author

ABSTRACT

The Texas Transportation Institute (TTI) 2007 mobility report shows traffic congestion is worsening in American cities of all sizes, creating $78 billion annual lost hours and 2.9 billion gallons of wasted fuel per year. Meanwhile, aging roadway infrastructure needs to be frequently maintained to sustain their quality service for the traveling public. Compared to long-term construction zones, short-term work zones (6~8 hours long) are more frequent, but do not receive equal attention due to their low impact. Lane restriction or closure, however, is still inevitable for most maintenance activities and delay may happen even during off-peak periods. The accumulated impact of short-term closures due to their high frequency on a segment cannot be overlooked; especially if the segment carries large traffic volume during peak hours and/or off peak hours.

By using lane closure information and traffic data from the southeastern Wisconsin freeway systems, this study aimed to obtain a clear understanding of the dynamic nature of traffic demand and quantify it as a function of driver characteristics and corridor features. To be specific, the results of the study identify that, in general, a low density of signalized intersections along the arterial routes, high historical mainline traffic, and a short alternative route distance encourage drivers to divert. Consequently, traffic impacts at off-ramp terminals and arterial streets can be estimated via regression models, which in turn assist with informed decisions such as the deployment of advanced traveler information systems.

Key Words:

Short-term Lane Closure, Traffic Diversion, Gravity Model, Congestion Mitigation

INTRODUCTION

Urban freeway pavement conditions and infrastructure durability have deteriorated and have been affected by the large amount of traffic carried every day. To keep a constant level of service and maintain the same driving quality for travelers, highway rehabilitation and short-term maintenance activities (6~8 hours) are frequently performed before a major reconstruction is required. Consequently, a lane restriction or partial closure is inevitable in order to ensure an uninterrupted and safe area for construction workers. Because most maintenance activities are conducted in the daytime, they may create congestion and unnecessary delays to motorists. Due to the limited coverage of permanent changeable message signs (CMS), the deployment of portable CMS to disseminate traveler information has to be prioritized and optimized due to the large number of requests. Normally, the portable CMS deployment is decided based on the particular lane closure and a delay assessment for the selected corridors. Historical traffic data collected through loop detectors is able to distinguish the high traffic demand locations in normal conditions, but fails to consider demand changes in congested conditions. Previous research shows that drivers are fairly responsive to a potential or existing congestion situation through their own observation and judgment, a phenomenon called "natural diversion", which reduces the normal demand by up to 30%.

Compared to the long list of publications in the area of congestion mitigation and safety impacts for long-term work zone activities and recurrent bottleneck congestion, studies on the traffic impact associated with short-term work zone activities are relatively limited. One of the plausible reasons for lacking the needed attention may be because of the underestimated delay caused by these short-term lane closures and restrictions. It is understood that the work zone activities, primarily maintenance work, last between six to eight hours, often scheduled during the daytime off peak period. Unlike their long-term counterparts, it is unusual for short-term work zones to be equipped with any advanced traveler information (ATI) equipment because of their high frequency and short approval lead time. However, a lane restriction or partial closure is necessary during the construction or maintenance, which will interfere with traffic especially in the urban freeway environment, where a longer peak periods and inappreciative difference between peak and off-peak periods exist. Again, when considering the high frequencies of such lane closures or restrictions, the cumulative traffic impact will be significant.

The goal of the study is to obtain a clear understanding of the dynamic nature of traffic demand and quantify it as a function of driver characteristics and corridor features. As a representative of other urban metropolitan areas in the country, southeastern Wisconsin, including the City of Milwaukee, consists of a massive urban freeway system and a well-connected arterial network. The Wisconsin Department of Transportation (WisDOT) State Traffic Operational Center (STOC) maintains a computerized Lane Closure System (LCS) where thousands of lane closure events have been registered. The WisLCS provides a generalized observation of the impact of short-term lane closure or restriction in an urban environment and establishes a foundation for developing lane closure delay models. With the WisLCS, this research study was expected to identify the key elements causing or mitigating delay related to short-term lane closures and develop realistic prediction models for estimating congestion demand without ATI.

LITERATURE REVIEW

Drivers route choice behavior during congestion has been a prolific area in travel demand studies where abundance publications cover a broad spectrum of topics. Abdel-Aty et al. constructed five different scenarios of traffic information and explored drivers' diversion decision under each of them (1). The five scenarios addressed included: no information, pre-trip information without and with advice, and en-route information with and without advice. The results show extra information such as advice would encourage drivers to divert from their normal routes; expressway users are more likely to divert; and high number of traffic signals on the normal route increase the diversion probability. With the flourish of infrastructure-based traveler information systems and real-time personal travel information subscriptions, motorists have access to a plethora of information that may change their driving patterns and assist them with better route choice to avoid unnecessary or excessive delays. Accordingly, research interest, with the special focus of en-route information provided via Variable Message Signs (VMS) has grown.

Khattak et al. investigated commuters' diversion propensity using stated preference method. Respondent drivers expressed a higher willingness to divert if expected delays on their usual route increase and if the congestion was non-recurrent (2). A combined revealed and stated preferences conducted by Polydoropoulou et al. indicated expected delays in the usual route, travel time on alternative routes, perceived congestion level on alternative routes, and information sources are important determinants of diversion (3). Levinson, et al. studied the impact of real-time incident information disseminated via VMSs on urban drivers' decision-making, with a focus on the content and timing of the information (4). The study showed, through detailed VMS logs, that the diversion rate was significantly impacted by factors such as the nature of the incident, time period, type of message, alternative exit availability and their interactions. Chu et al. observed a decrease in the maximum mainline delay via detector data and further suggested that Advanced Work Zone Information Systems improved safety by smoothing traffic flow (5). A follow-up commuter survey confirms that approximately ninety percent of travelers thought that the estimated travel time was accurate and more than 70 percent of drivers changed their travel pattern; such as travel schedules, trip routes, and modes. Other studies conducted in Wisconsin focusing on the rural and suburban congestion caused by work zone activities evaluated the effectiveness of traveler information in several different aspects, including the type of information dissemination, the format of the message, the placement of the message board, the frequency, etc (6).

In spite of all the information provided through ATIS or based through drivers own perception, the action of diverting is individual decision that is closely related to drivers' personality and socio-economic characteristics. The significant socio-economic factors include education level (1), familiarity of the network (7), and personal characteristics such as risk averse, risk seeker and risk neutral (8). On the other hand, some studies have yield rather controversial results, stating that most demographic variables have little influence on motorist attitudes about VMSs, except for a few cases (9). Adbel-Aty also argued that age, gender, income and driving experience were found uncorrelated with drivers' diversion from the normal route decision (2).

In contrast, the research on drivers diversion behavior during the non-recurrent, i.e., incidence-induced or work zone related congestion without traveler information is very limited. The diversion decisions, however, are not unusual. The most relevant study on this particular topic discusses the changing traffic demand upstream of work zones without any assistance of traveler information, referred by Ullman as "natural diversion" (10). "Natural diversion" occurs when drivers decide to leave the freeway by off-ramp locations or not enter the freeway at on-ramp locations to avoid congestion based on their observations of prevailing traffic conditions.

According to Ullman's study, a significant reduction in entrance ramp traffic upstream of lane closures and a limited reduction in exit ramp traffic were observed. Ullman developed mathematical equations to model the percentage of natural diversion volume using energy analogy of traffic flow (11). The phenomenon was later proved in a separate research project in Wisconsin where stabilized queues were observed due to natural diversion (12).

Both Ullman and Lee suggest that this issue be further studied to calculate the correct traffic impact caused by short-term lane closure through additional information regarding traffic volume, work zone capacity, and queuing length. A database or methodology can then be developed to estimate the major factor, corridor permeability, describing the diversion potential of a roadway corridor. Furthermore, the impact of diverted traffic to surface arterials and their neighborhoods as well as upstream exiting ramp terminals may be significant because the signal timing at these locations may not respond well a traffic volume surge.

DATA COLLECTION AND PROCESSING

In order to accurately capture the field traffic variations due to short-term lane closures, real-time traffic information as well as the lane closure times and location are needed. Thanks to the deployment of WisLCS and the Volume, Speed, and Occupancy Application Suite (V-SPOC), extensive data were readily available. WisLCS is a web-based system used to track closures and restrictions on Wisconsin state highways, including ramps. The important data elements in WisLCS include, but are not limited to, closure configuration such as the number of lanes closed, closure status, closure date, approved date, duration, and location including road name, latitude and longitude. The short-term lane closures defined in this study are closures lasting fewer than twelve hours and those not providing previous notice or detour information to the user. Data collection started in January 2008 when the system was initiated and ended in April 2008. More than 5,500 closures have been logged; among them 340 were preliminarily identified as possible short-term lane closures. All of the studied closures were limited to the Wisconsin southeast freeway system in the Milwaukee area.

Along with WisLCS, the V-SPOC application suite is a web-based toolbox for analyzing state highway traffic detector volume, speed, and occupancy data from the WisDOT Advanced Traffic Management System (ATMS) data archive for the years 1997 to present. The data are archived in intervals of 30 seconds and can be conveniently aggregated to interval such as 1-min, 5-min, 15-min, and so on. Of our interest is the data regarding detector location, historical detector volume, speed, and occupancy including both mainline detectors and ramp detectors. The development of an automatic connection between V-SPOC and WisLCS is still in progress. In other words, to utilize and relate volume, speed, and occupancy information collected through loop detectors on highways and ramps to individual short-term closure events, the two data sources have to be linked manually. A methodology was developed to link each lane closure location to corresponding available loop detectors graphically. As illustrated in Figure 1a, the methodology includes joining the data from different databases in order to allow a map representation of the WisLCS closure. Since the database information is joined based on an online mapping service, it was required to design a procedure that allows importing the corresponding data into a GIS software tool. The second dataset that needed to be visualized corresponds to the loop detectors included in the V-SPOC database. As opposed to the WisLCS location information, V-SPOC does not provide any information beyond the name of the street on which each detector is located as well as a corresponding detector ID. An undergoing project at WisDOT includes plotting each detector in the V-SPOC system and the corresponding ID on hardcopy as-built plans. Thus, using the as-built plans from this project, an online mapping tool was used to mark each of the loop detector locations. Taking advantage of satellite images, each of the loop detectors was correctly located with lane-by-lane precision. Once over 800 loop detectors were correctly plotted and stored in the online mapping tool, all of the detector data can be linked with the closure information as shown in Figure 1b. Having all of the data plotted on one map allows one to visually identify which loop detectors are located inside the closure as well as the detectors located upstream of the closure, a crucial process in the determination of queue length as well as speeds during the closure.

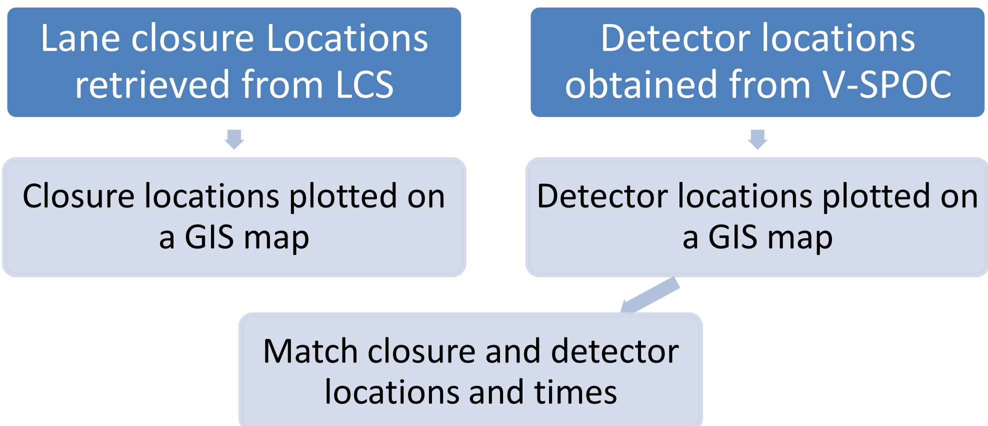

FIGURE 1a Conceptual data integration process.

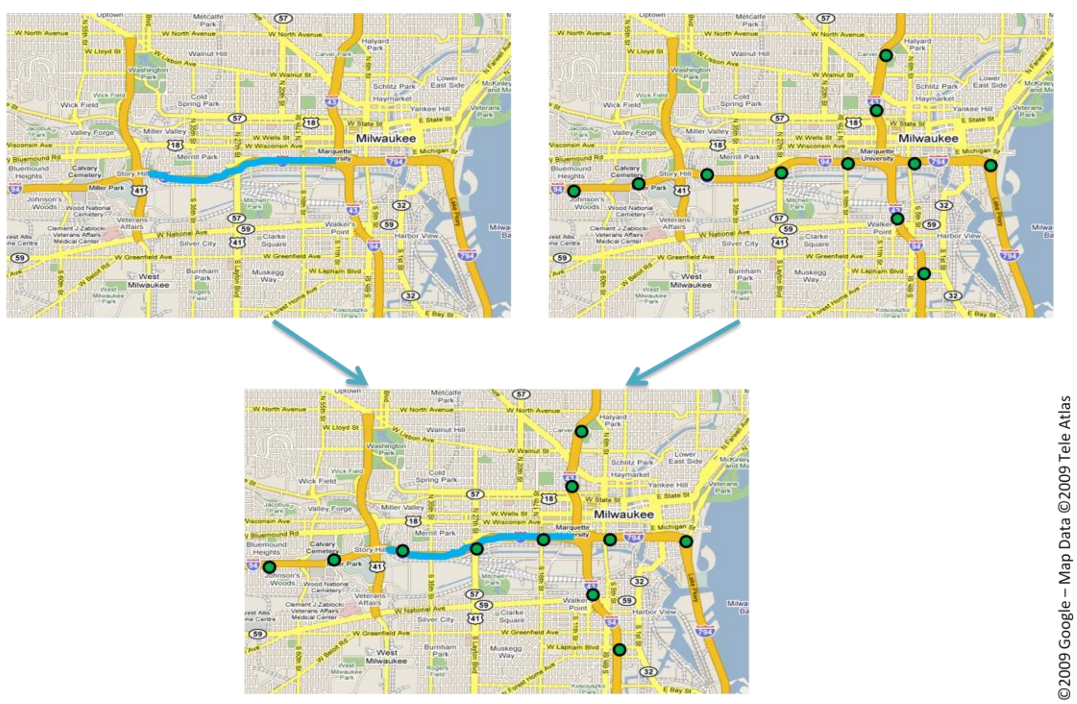

FIGURE 1 Conceptual data integration process and the result of it.

However, after linking the two systems, the discrepancies between data required further effort to perform data quality control and assurance. The in-depth investigation found that the differences are caused by one or more of the following reasons:

1. Length of the closure, in terms of time, is often overestimated. V-SPOC data often shows closure ending sooner than expected as well as closures starting after the scheduled time.
2. Closures are often not marked as completed. The person who entered the closure in the system never changes it to completed status.
3. Scheduled closures did not take place. V-SPOC data shows normal volumes on all lanes while the LCS says there is a closure at the corresponding detector location.
4. Shoulder work sometimes is scheduled as the closure of one lane. V-SPOC data shows normal volumes on 'closed' lane but with significant speed reductions.
5. Location misrepresentation. The Latitude and Longitude coordinate for a closure in the LCS database corresponds to a location outside the county where the closure is supposed to take place.
6. Detectors failed during the scheduled closure and thus no data is received by WisDOT from those sites.

Finally, a small number of lane closure events were retrieved and confirmed. The reasons for a relative small number of samples compared to a large amount of lane closure events are:

1. Lack of V-SPOC data for some closures appearing on WisLCS.
2. No loop detectors installed at the location of the closure.
3. The starting point of a several number of closures is located near an interchange which makes it unfeasible for analysis because the conditions of speed and volume near the closure cannot be obtained.

In order to understand why motorists decide to divert without being notified and identify the factors contributing to their decision-making, several additional data elements were collected, primarily from local streets. These variables are considered a good representation of either appealing or unattractive reasons for travelers to divert, or not divert, from mainline streets in order to avoid delays. The following data were collected via a collection of means such as Google Maps, etc.

1. Exit density upstream of the closure,
2. Entrance density downstream of the closure,
3. Alternate route length,
4. Posted speed limit on alternative route,
5. Area covered by alternative route,
6. Parallel distance between mainline and alternative route,
7. Signalized intersection density on alternative route, and
8. Unsignalized intersection density on alternative route.

After further data reduction, there were 13 lane closure events containing all available traffic conditions, alternative route information, and observed congestion. The length of each closure varies between 3 and 8 hours. Using one hour as the analysis interval, a total of 62 observations were collected for the study. Note that the short-term lane closures that did not cause any traffic congestion or mainline speed reduction have been removed from the dataset because it was assumed that no drivers would divert under free-flow conditions. All the variables are summarized in Table 1.

TABLE 1 Variable Summary Table.

Variable	Min	Max	Average	Std. Dev.
Density Exits Upstream (exits/mile)	0.367	2.174	1.026	0.342
Density Entrances Downstream (ent/mile)	0.474	1.442	1.026	0.342
Alternate Route Length (miles)	2.1	3.7	2.63	0.645
Change in Speed at Closure (MPH)	-35	5.4	-22	13
Historical Mainline Volume (Vehicles)	1,200	1,730	1,410	120
Posted Speed Alternate Route (MPH)	35	45	37.7	4.5
Area Covered by Alternate Route (Sq. Miles)	40	755	334.5	216
Parallel Distance from Mainline (Miles)	0.03	0.32	0.19	0.52
Signalized Intersection Density (int/mile)	0.811	3.793	4.879	2.325
Unsignalized Intersection Density (int/mile)	14	32	23	5.49

In Table 1, the values for density downstream and upstream are computed by measuring the shortest distance from the start and end of the work zone that contains three entrances and exits correspondingly. Thus, if three exits are spread over 3 miles upstream of the work zone then the corresponding density is 1.0 exit/mile. Signalized and unsignalized intersection density was measured by taking into consideration how many of the corresponding intersections a driver has to navigate when following the shortest alternate route.

METHODOLOGY

Isaac Newton described the law of gravitation in a relationship where the relative force between two objects is proportional to the mass of both objects and inversely proportional to the square of the distance between the two. The simple logic is well suited for other areas of study where the modified version of the Law of Gravitation has been widely used to predict movement of people, information, and commodities between locations. In urban planning, Casey (1955) is probably the first to apply a gravity model to describe the relationship between the number of shopping trips and populations of the towns of origin and destination as well as the distance between them. The model was further generalized by replacing the squared distance with a decaying function that represents the travel time, or the value of time. The same model, expressed in the following functional form, was adopted in this study to describe the incentives for motorists to take alternative routes.

$$\delta = \frac{P \cdot A}{f(cost)} = \frac{(\boldsymbol{X\beta})^{\alpha} \cdot H_v}{f(cost)} \qquad (1)$$

Where:

δ = Number of Trips that are diverted, a difference between historic flow rate and flow rate during the lane closure;
P = trip production;
A = trip attraction;
H_V = Historical Main Volume, a surrogate variable for demand or trip production
$\boldsymbol{X}$ = the vector of covariates representing the attractiveness of the alternates
$\boldsymbol{\beta}$ = the vector of coefficients for the covariates

Two popular cost functions were proposed and tested:

$f(cost)=L_A^2$, and $f(cost)=exp(L_A)$

Where:
L_A = length of the alternative route.

In urban planning, the gravity model is applied for generating an OD matrix for projected traffic growth by constraining either future trip ends production, attraction, or both. Given the known traffic diversion, the gravity model in this study was used to estimate the unknown coefficients α and β via linear regression after a logarithm transformation of Equation 1.

Another simple linear model was also used to model the relationship between relative mainline demand reduction and other explanatory variables. The relative mainline demand is defined as the ratio of the diverted traffic to normal traffic demand. The linear model can be expressed as the simple function shown below:

$$RR_i=\boldsymbol{X_i\beta}+\varepsilon_i \quad (2)$$

Where,
RR_i = the relative mainline demand reduction for closure event *i* and $\boldsymbol{X}$ is the vector of independent variables of interest.

The employment of regression models serves two purposes: 1) to identify the factors that can help to explain and predict the route choice decision; and 2) to estimate the traffic stress on ramp terminals, especially the exiting ramp terminals as well as the traffic impact on (alternative) arterial routes. Predicting negative traffic impact due to short-term lane closures provides an effective link to historical data that can be used to make informed decisions. Recommendations are provided in the following section.

ANALYSIS AND DISCUSSION

All of the closure related information (the information presented in Table 1) was combined with the corresponding volumes and speeds obtained from V-SPOC. Thereafter, the data was organized in a way that each case represents the reduction in volume on the mainline or the increase in exit ramp volume as a function of the variables in Table 1. As mentioned before, there were a limited number of sites available for analysis, so to increase the number of observations, a 15-minute moving time window was used and then aggregated into one hour. Each case in the dataset contains a vector with a reduction in mainline volume and increase in the exit ramp volume plus other vectors of explanatory variables.

General Considerations

Even during the off-peak period, congestions and delays may occur because of the reduced mainline capacity. The results show that up to 15 percent of traffic will divert without any advanced traveler information, so called natural diversion, during the time intervals when the traffic flow rate exceeded 1,000 vehicles/hour/lane, with an increasing diversion trend with increasing mainline demand. The relationship can be clearly illustrated in Figure 2 where traffic flow rates (15-min interval) during construction are plotted as a function of the flow rates at the same location during the weeks prior to the closure.

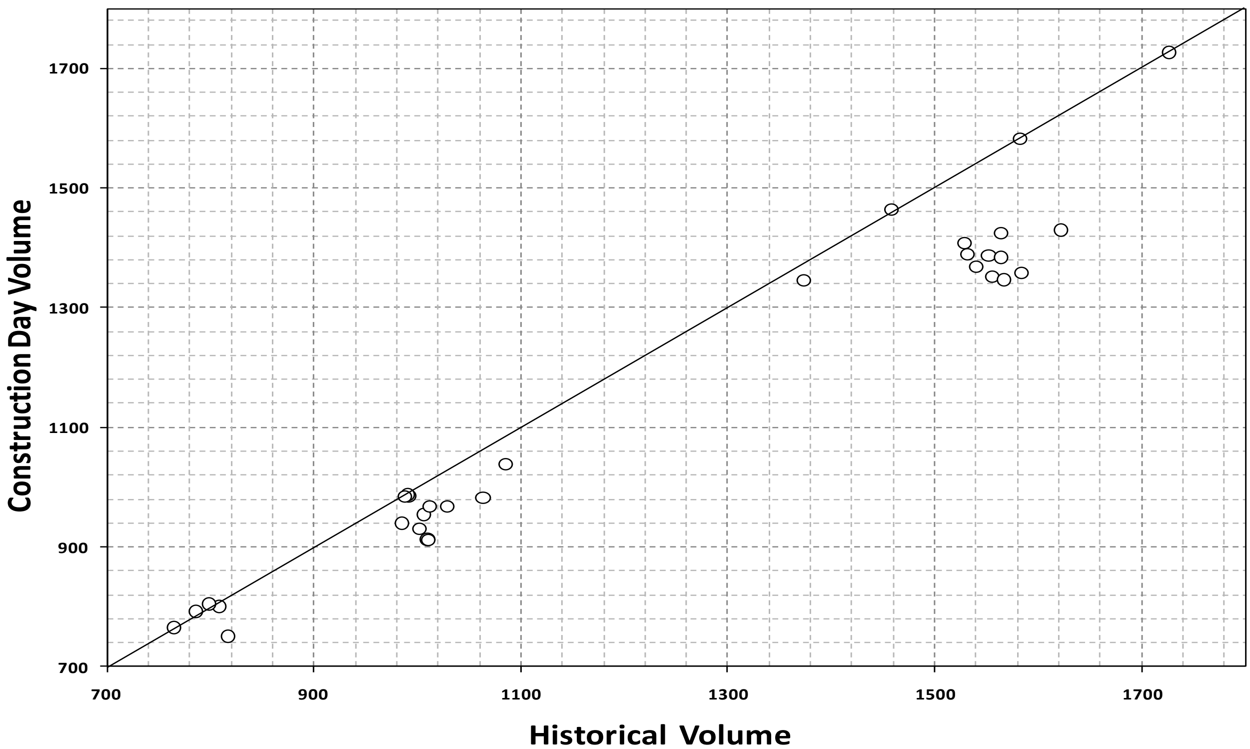

FIGURE 2 Construction Day Volume at Closure Vs. Historical Volume

The changes in the traffic flow rates between historical and closure periods unambiguously suggest that traffic diversion happened. But with similar historical flow rates, diversion rates were higher at some locations or corridors than the others. The location-specific or corridor-specific variation indicates that some factors may be able to explain what causes the differences. All the arterial data were collected based on their potential of attracting or deterring motorists to divert in order to avoid possible or excessive congestion, presuming that the motorists have some knowledge of surface traffic and roadway conditions. Some factors were correlated to each other, whose relations were revealed through the Pearson correlation test. To avoid correlated variables while allowing the most valuable variables to be identified, variables were gradually added to the models, starting from the univariate model, then two variables, and so on. Only two-way interaction was considered to keep the model simple and appealing for application. After a series of model tests, the candidate variables were reduced to five:

- Entrance density downstream of the closure,
- Speed difference between normal and lane closure conditions,
- Normal (historical) mainline volume,
- Length of the alternative route, and
- Signalized intersection density in the alternative route(s).

Gravity Model for Diverted Traffic

Gravity model results in Table 2 show that the statistically significant variable at a 5% level of significance is the signalized intersection density on the alternative route, which appears to be a major concern for motorists leaving the freeway. The higher the signalized intersection density is, the lower the observed diversion.

TABLE 2 Model results.

Gravity Model		Estimate	Std. Err.	t-Val	p-Val	R^2
$\partial = \frac{(x\beta)^{\alpha} H_v}{L_A^2}$	β	0.259	0.007344	35.271	<0.000	0.34
	α	3.027	0.477949	6.334	<0.000	
$\partial = \frac{(x\beta)^{\alpha} H_v}{\exp(L_A)}$	β	0.327	0.01187	27.574	<0.000	0.34
	α	3.317	0.50286	6.596	<0.000	

Linear Model for Relative Mainline Demand Reduction

As a comparison to the gravity model structure, a simple linear model was considered where the dependent variable was the relative mainline demand reduction instead of the absolute value of diverted traffic. Several linear models have been tested and two final models were chosen because of their effectiveness in describing the attractiveness of the alternative routes. Similar to the gravity model, and also a linear model after a log transformation, high signalized intersection density makes the arterial route less desirable. The speed differential, an important congestion index, between normal and lane closure days proves that the higher the speed difference is, indicating a high possibility of congestion, the higher relative diversion will occur. Though R-square suggests that the simple linear models perform better than the gravity models, the difficulty of applying the speed differential factor is that the speed information on lane closure day will not be available for traffic congestion mitigation planning. However, it is possible that an estimated speed reduction may be recommended if the linear models are used.

TABLE 3 Linear Model Results.

Model	Variable	Coeff.	Std. Err.	T-Val	P-Val	R^2	Adj. R^2
Model 1	Intercept	0.03009	0.01646	1.83	0.073		
	Signalized Dens.	-0.031272	0.006399	-4.89	<0.000	0.588	0.574
	Delta Speed	0.0038573	0.000463	8.32	<0.000		
Model 2	Intercept	0.02399	0.01954	1.23	0.224		
	Density Downstream	-0.06542	0.1823	-3.59	<0.000	0.525	0.509
	Delta Speed	0.003857	0.00463	8.32	<0.000		

Linear Model for (Exiting) Ramp Traffic

Figure 3 illustrates the difference in traffic flow rates between normal (historical) and lane closure periods. It is obvious that the increase of exiting traffic was considerably higher during the lane closures. It could become a problem if the off-ramp terminal signal is not responsive to the surge of exiting traffic during the off-peak periods. The excessive exiting traffic, if not dissipated in time, will form a queue on the off-ramp and even worse, may spill back to the mainline, which will severely affect safety and operational efficiency. Therefore, it is important to estimate the possible stress on the exiting ramp terminals caused by the diverted traffic. Though the increased traffic may not be a threat given the current ramp capacity, attention needs be raised to proactively manage the exiting ramp traffic before serious traffic incidents happen.

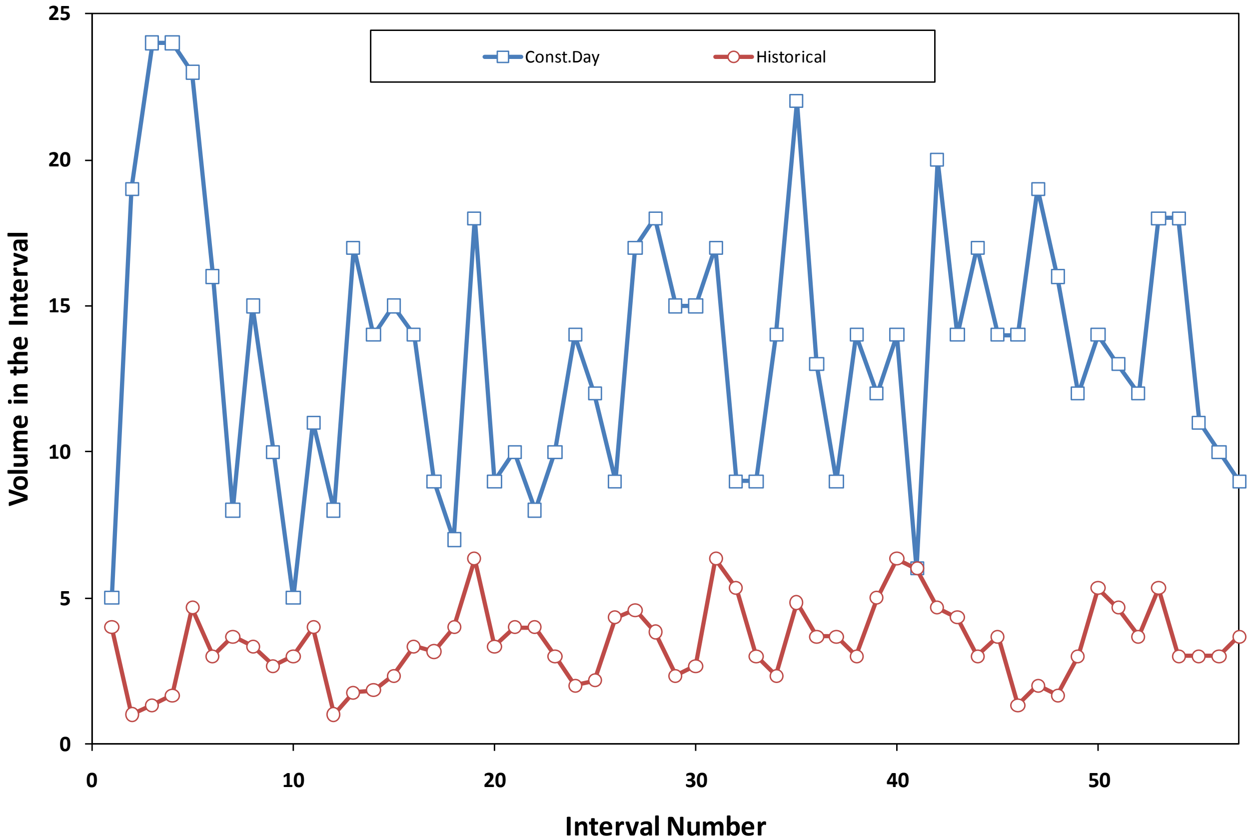

FIGURE 3 Typical ramp volumes on a five minute interval basis.

Table 4 presents the estimated coefficients for variables that predict exiting ramp traffic. Similar to the relative mainline demand reduction model, two statistically significant variables are ramp entrance density downstream of the beginning of lane closure and speed difference. A high R-square value indicates that the two variables along with the intercept can explain 75% of the ramp traffic increase. If the two factors are known, the off-ramp traffic increase can be easily calculated. The factor of entrance density downstream is readily available while the speed difference can be substituted with an estimated value for future application.

TABLE 4 Linear model for exiting ramp traffic.

Variable	Coefficient	Std. Err.	T-Val	P-Val	R^2	Adj. R^2
Intercept	-0.9662	0.3296	-2.93	0.005		
Signalized Density	0.6052	0.3714	1.63	0.110	0.751	0.740
Delta Speed	-0.081473	0.009077	-8.98	<0.000		

In summary, the challenge of using the linear model to predict the exiting ramp traffic as well as the diverted traffic to the arterial street lies in the fact that the real speed difference is unavailable for planning any congestion mitigation strategies such as the deployment of traveler information. The inclusion of speed difference provides a good fit according to the R-square and is an important factor in predicting diverted traffic because it signals congestion. Gravity models, on the other hand, do not have desirable goodness of fit according to R-square despite their rational logic, implying that other factors, such as human factors, may affect drivers' route choice appreciatively. Due to the ease of data collection, the gravity model results can still be recommended as a means for predicting traffic diversion.

CONCLUSIONS AND FUTURE RESEARCH ACTIVITIES

With the continuous increase of travel demand, traffic congestion has become part of daily life. Every year, the delay cost by peak period traffic congestion is $710 per traveler (TTI 2007). The Texas Transportation Institute (TTI) 2007 mobility report shows traffic congestion is worsening in American cities of all sizes, creating $78 billion annual lost hours and 2.9 billion gallons of wasted fuel. Meanwhile, aging roadway infrastructure needs to be rehabilitated and reconstructed and deteriorated pavement needs to be resurfaced and repaved to sustain their quality service for the traveling public. Long-term work zones, due to their size, duration and impact, have been managed with extra efforts. For example, these projects usually categorized as level III and IV in the Wisconsin Transportation Management Plan (TMP) Guidance, which specifies work zone management strategies, traffic impact studies, ITS equipment, optimization of phasing and staging and public outreach. Short-term work zones, primarily maintenance activities, on the other hand do not receive equal attention due to their low impact and high frequency. Lane restriction or closure, however, is still inevitable for most maintenance activities and delay may happen even during the off-peak periods. Sometimes, due to the conflict of scheduling, such activities can be advanced or postponed to a time that overlaps with the peak period when the congestion can be more pronounced. The accumulated impact of short-term closures due to the recurrent maintenance on a segment cannot be overlooked; especially when the segment carries large traffic volume during peak hours or off peak hours.

In this study, after a careful review of the Wisconsin Lane Closure System (WisLCS), a total of 13 lane closure events were used. The reasons for a relatively small number of samples compared to a large amount of lane closure events are detailed in the data collection section with the primary reason of data quality. The study designed a novel approach to integrating two state-wide data management systems, WisLCS and V-SPOC with detector data to estimate the traffic impact on both ramp terminals and alternative arterial routes. The results show that up to 15 percent of traffic will divert without any advanced traveler information, so called natural diversion. A number of factors such as mainline exit density, entrance density, alternative route length, posted speed limit, signalized intersection density, unsignalized intersection density, etc have been tested to identify which the drivers' decision to divert or not. Both gravity and simple linear models suggest that signalized intersection density on the alternative route is the major concern to a diversion decision. A high signalized intersection density deters travelers from taking the arterial alternative routes. Linear models have a better goodness of fit because the speed difference between the normal and lane closure condition is included. Though speed difference is an important indicator of possible congestion, it is only available when a lane closure happens, which does not apply to the operational planning. In general, a low density of signalized intersections along the arterial routes, high historical mainline traffic, and a short alternative route distance encourage drivers to divert. Off-ramp terminals may have more severe traffic problems than arterial streets because of the surge of exiting traffic. If the signal timing at these ramp terminals cannot dissipate the exiting traffic in a timely fashion, a queue will form and spill back to the mainline, which is a clear trigger for possible crashes and congestion.

The study identifies the factors that help explain the traveler’s diversion behavior, constructs models to predict diverted traffic and provides data to make informed decisions such as the deployment of advanced traveler information with heavily impacted corridors. Despite the small sample size, the results focused on a few segments on I-90 and I-94. In the future, the approaches can be easily expanded to other segments in other corridors and more data and locations will be collected to enhance the models and results. Figure 4 shows the short-term lane closure intensity on all the corridors in the Southeast freeway network in the Milwaukee Metropolitan area. Combing the features of each corridor and its parallel arterial street conditions, a corridor traffic impact index caused by short-term lane closures can be developed. The index can be used to justify the deployment of ITS technologies or other traffic management strategies for mitigating congestion.

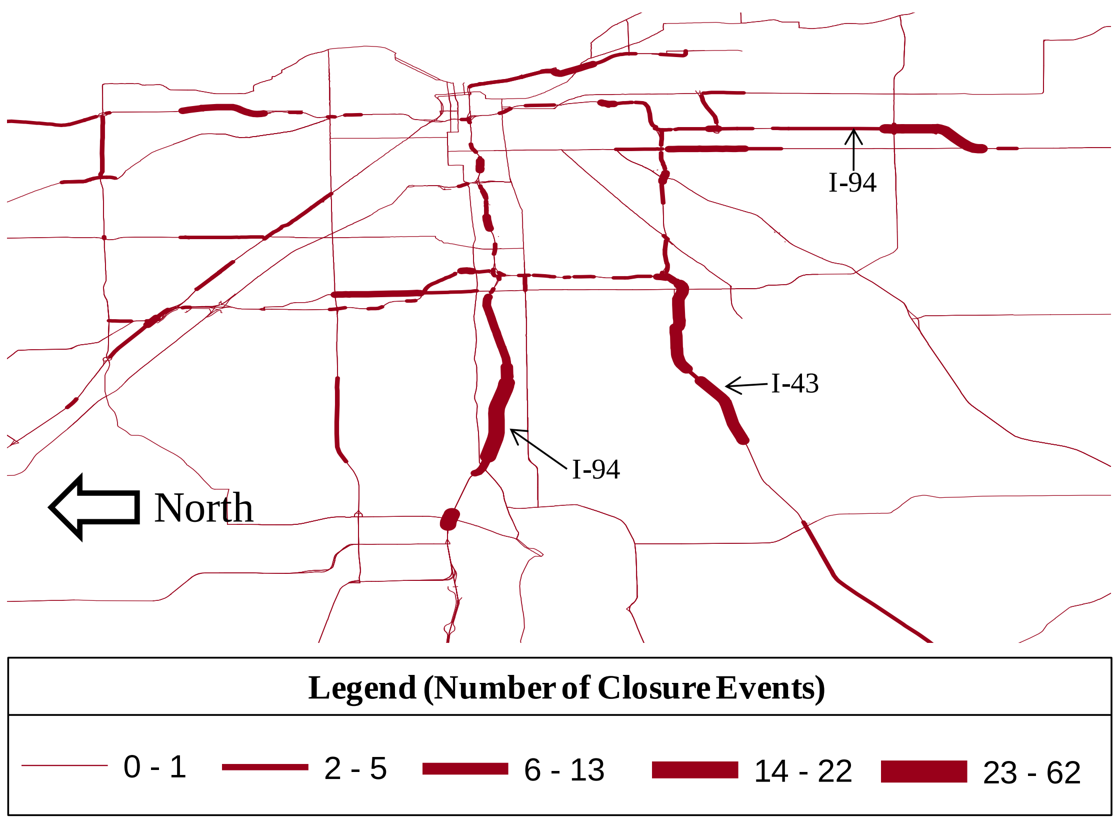

FIGURE 4 From January 2009 to April 2009

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