

# **A Method for Evaluating Traveler Information Systems**

by

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## A Method for Evaluating Traveler Information Systems

**Abstract:** Incidents account for nearly 50% of traffic congestion in urban areas. The cost of incident-induced congestion is borne by motorists in terms of delays and higher vehicular costs. They also impose costs on commercial carriers and associated businesses. Mitigating the effect of incidents clearly benefits motorists and commercial users. This study provides a method for evaluating the impacts of dynamic traffic information disseminated through a variety of sources in reducing incident-induced congestion. The method can be used by State Departments of Transportation to decide expansion priorities for traveler information systems, taking into consideration their impacts on commercial and non-commercial users. Using a behavioral model, we simulate the movement of trucks and vehicles in a simple transportation network. The results show the benefits of providing real-time information to travelers in incident-induced congestion situations, and capture the different effects of traveler information according to different user/vehicle behaviors, including commercial carriers.

**Keywords:** traveler information, trucks, traveler behavior, intelligent transportation systems

### INTRODUCTION

Traffic congestion is a growing problem in the US, as was recently pointed out in a Transportation Research Board report (1). Incidents are known to contribute nearly 50% of total traffic congestion in urban areas (2). The costs of incidents are borne by motorists and commercial movers. Motorists experience delays, late arrival at destinations, higher vehicular costs, added travel time uncertainty, and increased pollution. Commercial carriers, and associated businesses, experience vehicle and driver costs of delay, late incoming/outgoing deliveries, and the cost of keeping additional inventory. Motivated by these facts, there is a clear need to pay considerable attention to reducing incident-induced congestion in urban areas and start monitoring traffic conditions on routes where incidents may occur and alternate routes which may receive diverted traffic. One way of diminishing the negative impact of incident-induced congestion is to disseminate real-time traffic information to travelers.

It has been found that provision of real-time traffic information about incidents has the potential to ameliorate traffic congestion by encouraging and assisting travelers to divert to alternate routes (3-5). The literature provides a range of benefits from information (Advanced Traveler Information Systems or ATIS), which vary from as low as 1% to about 30% in terms of time saved (6). ATIS services can achieve mobility objectives by giving travelers better information, pre-trip and en-route, thereby enabling them to make better transportation choices. Individuals or commercial users can now receive dynamic information through a variety of sources (internet, 511, TV/radio, kiosks, in-vehicle systems). While most large cities have traveler information on certain congested routes, State Departments of Transportation need methods by which they can assess the benefits of expanding information services to uncovered locations and various user groups.

Software such as IDAS, DynaMIT, and DYNASMART-P has emerged to help evaluate the impacts of information (7-9). Some of them account for how different types of road users/vehicles might have different responses even to the same traveler information. However, knowledge remains scarce about ATIS impacts across motorists and truck users, ATIS technology effectiveness, and whether it is accessible to a wide range of users and accepted/used by different groups of travelers in specific situations. The literature examining the differential traveler behaviors of various user types remains limited, with a few exceptions relating to the particular information needs of trucking companies (10-12).

The goal of this paper is to develop a framework for evaluating dynamic traveler information systems focusing on incident-induced congestion, but taking into account different user and vehicle behaviors and their different effects on network performance. A strong behavioral basis for user responses is emphasized and developed, where we tested different diversion probability of commercial carriers (trucks) from that of motorists (cars). Furthermore, in the simulation model, cars and trucks have different effects on traffic flow as well as network performance. The key issue addressed in this research is how to evaluate the impacts of ATIS on different users and/or vehicles, particularly accounting for how different levels of truck flows influence various performance measures.

The paper is organized as follows. The next section briefly reviews existing studies related to ATIS, incident-induced congestion, and truck traffic. Then, the conceptual framework for this research is introduced, followed by the methodology of the proposed traveler information

evaluation process. Next, the experimental results and relevant discussion are presented. Finally, a summary of important findings is provided and possible future work highlighted.

## LITERATURE REVIEW

### Traveler Information

Generally speaking, studies on traveler information technologies date back to the 1950s. Researchers at that time put great effort into creating urban traffic surveillance and control systems, which utilize traveler information technologies (5). True application of traveler information technologies started in the 1960s. Several transportation projects containing such technologies were fully implemented around the world by the 1970s (13-16). The primary goals of traveler information research and practice are better management of traffic flow, enhanced driving conditions, and improved traveler safety (5).

In recent decades, ATIS have emerged to support more informed travel decisions. Many studies have pointed out that disseminating real-time traffic information to travelers could offer significant benefits in terms of ameliorating traffic congestion, improving network performance, and enhancing travel safety, thus providing economic and environmental advantages (3-5). The literature further shows that real-time traveler information may be particularly useful in the context of incident-induced congestion (6, 17, 18), since real-time traffic information could reduce the uncertainty caused by incidents.

However, the true potential of disseminating real-time traffic information has not been thoroughly studied in the literature yet, although a few researchers have already questioned whether the impact of traffic information is known to a sufficient extent (19-21). For instance, Arnott (19) argued that traveler information technologies may counter-productively lead travelers to congest alternate routes, ultimately degrading network performance. A survey of driver response to traveler information in London (21) indicated that few drivers diverted based on the traffic information, although many found the information useful. Additionally, the impacts of disseminating information to various user groups, remains limited.

In addition, there have been worldwide efforts during recent decades to study various aspects of real-time traveler information technologies. One important aspect to evaluate is impacts of such technologies on travelers and the transportation system. Due to the scarcity of

field data on impacts of traveler information technologies, researchers have modeled them in laboratory experiments and through simulations. Models that could be used for real-time traveler information evaluation are IDAS, DynaMIT, DYNASMART-P, INTEGRATION, and PARAMICS (7-9, 22, 23). Although such models provide useful approaches to the study of evaluating real-time traveler information, they may not represent well the difference in motorist and commercial users.

### **Traveler Behavior**

The worldwide interest in real-time traveler information technologies is based on humans' propensity to modify behavior to suit new conditions (24-26). We assume that adaptations in traveler behavior will occur when travelers are provided with dynamic real-time traffic information, which could benefit individuals as well as the road network. However, Smiley (26) pointed out that one cannot simply look at changes in the targeted task, but rather at drivers' complex decision processes and their actual responses to real-time traveler information in evaluating traveler information technologies. Clearly, understanding traveler behavior is an important aspect for developing and evaluating traveler information systems.

Conceptual models of travelers' behavioral choices given travel information have been proposed by several researchers, including Haselkorn et al. (24), Ben Akiva et al. (3), Khattak et al. (4), and Adler & Blue (5). With regards to real-time traveler information, they found that en-route diversion behavior was influenced by source of traffic information, expected length of delay, regular travel time on the usual route, and anticipated congestion level on the alternative route as well. Therefore, these elements all should be incorporated when modeling real-time traveler information systems.

Accounting for traveler behavior is a critical aspect in evaluating traveler information systems. Some relevant studies have already conducted simulation models or proposed theoretical frameworks with consideration of behavioral characteristics (3, 6, 18, 19, 27, 28). However, there remains a lack of connectivity between drivers' actual responses to traveler information and system performance modeling tools.

### **Different User and Vehicle Effects**

On the one hand, different types of road network users should have different kind of responses even to the same traveler information, because of their particular characteristics and circumstances (29). For example, drivers of large trucks may have a lower tendency to divert than motorists in incident situations, and their re-routing might be subject to trucking firms' priorities. But studies considering such differential aspects of user behavior when evaluating traveler information technologies remains scarce, with a few exceptions of the particular information needs of trucking companies (10-12).

On the other hand, different types of vehicles also may have particular impacts on traffic congestion, especially on incident-induced congestion. First, the share of trucks in traffic could be a statistically significant factor affecting incident occurrence (30). Second, components of traffic flow such as percentage of heavy trucks may influence incident duration, i.e., large trucks may interfere more with incident clearance operations (31).

Moreover, network performance imposes different costs on commercial and non-commercial users, especially for incident-induced congestion. Traffic congestion is more costly for businesses than individual travelers (32). In addition to vehicle and driver costs of delay, the negative impacts of incident-induced congestion on businesses could be late incoming/outgoing deliveries, and the cost of keeping additional inventory, etc. Therefore, as a growing trend, truck traffic and business users should be specifically concerned with the negative impact of such congestion. In other words, we should pay attention to these particular commercial carriers / trucks during the course of modeling, developing, and evaluating traveler information systems.

## **CONCEPTUAL FRAMEWORK AND METHODOLOGY**

### **Conceptual Framework**

Based on what we have discussed above, we define the corresponding conceptual framework of this study as portrayed in Figure 1.

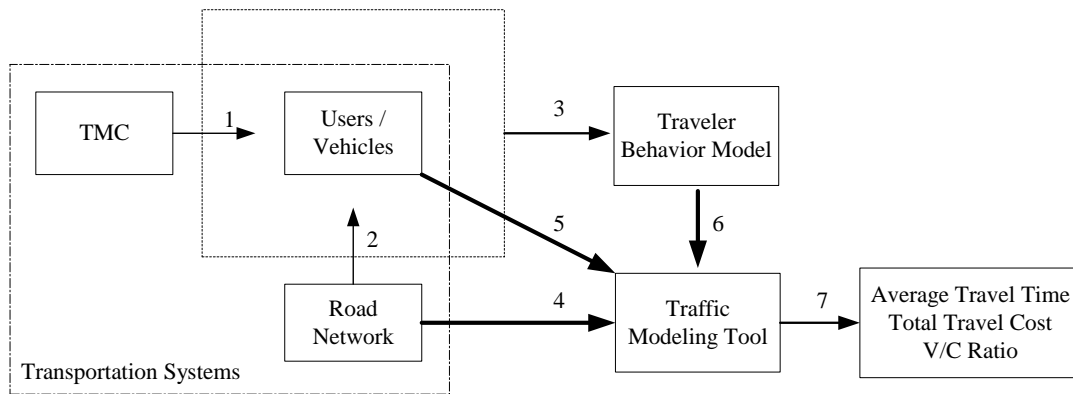


Figure 1. Conceptual Framework for Traveler Information Evaluation Process

Generally, the real transportation system can be represented as a combination and an interaction of users, vehicles, and road network, in which traffic management centers (TMC) also have an important role nowadays. When an incident occurs in the road network, a TMC could detect and respond to it quickly through various advanced technologies. One of them is to disseminate real-time traveler information to road users/vehicles (arrow 1). At the same time, users/vehicles themselves may or may not observe the incident-induced queue from the road network (arrow 2). These messages (whether a user/vehicle receives traveler information and whether a user/vehicle observes incident-induced congestion) are inputs to a traveler behavior model (arrow 3). The output of this behavior model is the travelers' route choice.

Three types of information are provided to the traffic flow modeling tool for evaluating the real-time traveler information. First, the road network information together with the traffic flow condition is needed (arrow 4). Then, user/vehicle information is needed, because we want to test whether information provides dissimilar benefits to different users and/or vehicles, under incident-induced congestion (arrow 5). Finally, travelers' route choice from the traveler behavior model is an important aspect for evaluating the traveler information system (arrow 6). Outputs of the composite modeling tool include network average travel time, total travel time, and volume over capacity (V/C) ratio, which are direct performance measures for the proposed traveler information evaluation process (arrow 7).

### Road Network and Incident

We use a simplified road network with five links but a single origin (point A) and a single destination (point C), as shown in Figure 2. There are several reasons to use such an idealized

road network in this study. First, we prefer a simple network to represent three types of travel behavior after providing real-time traveler information for an incident-induced congestion condition, i.e., do not divert; divert with returning to original route; and divert without returning. In addition, we need a simple network to test the effects of traveler information on different users and/or vehicles. It is important to do a comprehensive examination for these aspects in a simple network before extending it into large scale networks.

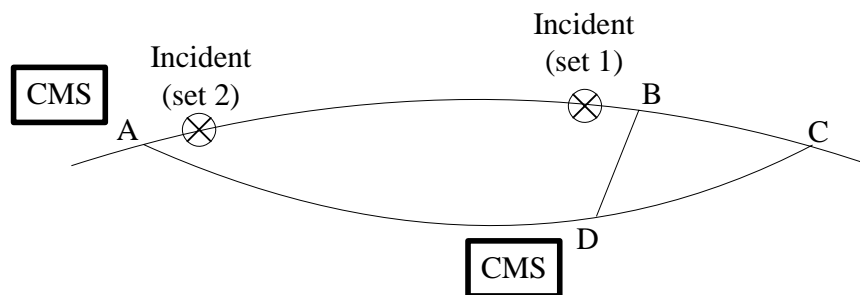


Figure 2. Idealized Road Network for This Study (Note: CMS – Changeable Message Sign)

Route ABC is a freeway with capacity  $\mu_1$  and free-flow travel time  $T_1$ , and Route ADC is an alternative route with capacity  $\mu_2$  and free-flow travel time  $T_2$ , where  $\mu_1 \geq \mu_2$  and  $T_1 \leq T_2$ . Link DB is a one-way route with capacity  $\mu_3$  and free-flow travel time  $T_3$ , where traffic flow can move from point D to point B; its capacity is not greater than route ABC and ADC.

Incidents are modeled to occur on link AB and when the traffic conditions are unsaturated. We examine two set of incidents. Incidents in Set 1 are near point B, where travelers cannot observe the incident-induced queue and cannot divert to the alternate route by themselves. By contrast, incidents in Set 2, which occur near point A, can be observed by travelers; and travelers themselves (without ATIS) may respond to incident-induced congestion and switch routes at point A. Within each set, we consider 11 scenarios with different percentages of travelers who could receive real-time traffic information (as shown in Table 1).



Table 1. Incident Scenarios Modeled

Set 1	Set 2
With info and can't observe	With info but can observe
0%	0%
10%	10%
20%	20%
30%	30%
40%	40%
50%	50%
60%	60%
70%	70%
80%	80%
90%	90%
100%	100%

### Traveler Behavior Model

In this paper, we add a traveler behavior model into the traveler information evaluation process, which should reflect drivers' actual response to traffic congestion information. Such a model would be useful for testing differences in effects of traveler information due to different road user/vehicle behaviors, since different types of road users and vehicles may have distinct traveler behaviors. Therefore, we choose a behavioral model based on a survey of travelers (33). The proposed binary logit model of route choice was estimated using the responses of those who knew about the traffic delays either by observing them or through traffic information. The model parameters can be changed to reflect the local conditions, if behavioral data are available.

Driver attributes were not included in this study, in order to focus on the information effect and simplify the analysis process. The dependent variable ( $Y$ ) was the decision of staying on the usual route ( $Y=0$ ) or diverting to an alternate route ( $Y=1$ ). The independent variables were information source ( $X_1=1$  if delay information received electronically,  $=0$  if delay received via observation) and travel time difference (in minutes) between original and alternate routes ( $X_2$ ). Table 2 presents  $\beta$  coefficients of the model as well as a sensitivity analysis of parameters. The constant term,  $\beta_0$ , is the log odds ratio of the diversion probability given that the other two  $X$ s are zero. Its value is negative and statistically significant, indicating that travelers prefer to stay on their usual route in unexpected delay situations, all else being equal. This is possibly due to their inertial tendencies (33). The 90% confidence interval for each  $\beta$  is calculated. For each beta, we compute the diversion probabilities for the four scenarios at its lower and upper interval bound, given that the other two betas are fixed to their point estimates.

The four scenarios are represented by the four combinations of different values of  $X_1$  and  $X_2$ . It turns out that the probability of diversion is quite sensitive to changes in  $\beta$ s, especially  $\beta_0$  and  $\beta_1$ . It also can be shown that the probability of diversion increases with  $\beta_i$  given all other  $\beta$ s fixed to their point estimates.

Table 2. Travel Behavior Model and its Parameter Analysis

Variable	$\beta$	t-statistics	90% Confidence Interval	Scenario	Probability of diversion
Constant	$\beta_0 = -0.717$	-4.27	[-0.993, -0.441]	$X_1=0;X_2=0$	[0.27, 0.39]
				$X_1=0;X_2=10$	[0.32, 0.45]
				$X_1=1;X_2=0$	[0.36, 0.49]
				$X_1=1;X_2=10$	[0.41, 0.55]
Electronic Information	$\beta_1 = 0.407$	1.88	[0.051, 0.763]	$X_1=0;X_2=0$	[0.33, 0.33]
				$X_1=0;X_2=10$	[0.38, 0.38]
				$X_1=1;X_2=0$	[0.34, 0.51]
				$X_1=1;X_2=10$	[0.39, 0.57]
Travel time difference	$\beta_2 = 0.022$	3.48	[0.012, 0.032]	$X_1=0;X_2=0$	[0.33, 0.33]
				$X_1=0;X_2=10$	[0.35, 0.40]
				$X_1=1;X_2=0$	[0.42, 0.42]
				$X_1=1;X_2=10$	[0.45, 0.50]

Note: Summary statistics – Initial log-likelihood  $L(0) = -257.85$ , Convergence log-likelihood  $L(\beta) = -246.71$ ,  $N=372$ .

We use these coefficients in our study for illustration. In the experiments carried out later, we study two different situations: in the first, commercial carriers behave similarly to motorists (equal diversion probability), while in the second the diversion probability of commercial carriers is assumed to be half that of motorists. Based on the travel behavior model, the probability of road user  $n$  choosing the alternate route  $P_n(\textit{alternate})$  could be calculated, where the probability of user  $n$  choosing the original route  $P_n(\textit{original}) = 1 - P_n(\textit{alternate})$ . Then, a random number  $\tau$  is generated between 0 and 1. If  $\tau$  is not greater than  $P_n(\textit{alternate})$ , then this user is assigned to the alternate route; otherwise this user is assigned to the original route.

### Traffic Flow Modeling

We use the FREEVAL model in this study to estimate the effects of queuing and vehicle delay for traffic flow, even for incident conditions. FREEVAL replicates the freeway facility methodology in Chapter 22 of the Highway Capacity Manual 2000 (34), which enables modeling of the effect of incidents on traffic operations macroscopically. Table 3 shows us the basic inputs FREEVAL needs as well as the major outputs it provides. We compile a macro to represent the

proposed traveler behavior model, which is combined with the FREEVAL modeling tool for evaluating a traveler information system.

Table 3. FREEVAL Inputs and Outputs

Basic Inputs	Major Outputs
- Facility parameters, e.g., location (urban or rural), terrain, type of segments, length, number of lanes etc.	- Mainline vehicle mile traveled (VMT)
- Network parameters, e.g., segment demand, on-ramp and off-ramp demand, free flow speed, truck percentage, etc.	- Mainline vehicle-hours travel time
- Modeling parameters, e.g., interval duration, number of intervals, number of segments, capacity adjustment factor, etc.	- System vehicle-hours delay
	- Mainline speed
	- Average mainline travel time
	- Segment V/C ratio
	- Segment vehicle level of service (LOS)
	- Graphs for V/C ratio, speed, and density

Based on the proposed road network, with real-time traveler information for incident-induced congestion, we examine three types of traveler decision processes, i.e., not divert; divert with return; and divert without return. Table 4 summarizes the modeling tool developed in this study, which matches the corresponding travel behavior respectively. Additionally, we consider different user/vehicle effects in the modeling process. We design different experiments with different commercial user/truck flow percentages, i.e., 5%, 10%, and 15%. Note that the modeling tool uses the passenger-car equivalent factor to simulate trucks (sometimes also including buses) in the traffic flow, which is a widely used approach in transportation research and study. Those equivalency values ( $E_T$ ) are adequate because they vary based on different traffic and roadway conditions and they are calibrated by empirical studies. To be more specific,  $E_T$  represents the number of passenger cars that would use the same amount of freeway capacity as one truck/bus, respectively, under prevailing roadway and traffic conditions (34). In this study, the value of  $E_T$  is 1.5.

Table 4. Summary of Model Design

Traveler Decision Process	Composite Modeling Tool
1. Travelers (both motorists and commercial users) tend to not divert no matter whether they receive traveler information.	1. Vehicles (both passenger cars and trucks) take the usual route ABC.
2a. Travelers tend to divert to the alternative route and return to the usual route if possible 2b. Travelers tend to switch to the alternative route and get to the destination (not return to the usual route). (Note: commercial users might have different diversion probability comparing to the diversion probability of motorists.)	2. Vehicles are assigned according to the travel behavior model 1) at point A, which is to determine the probability of route choice between link AB and BC; 2) at point D, which is to figure out the probability of route choice between link DB and DC. (Note: different rate of diversion probability between trucks and passenger cars are tested, i.e., 100% (exactly same), 75%, 50%, 25%, and 0% (trucks are not allowed to divert).)

Figure 3 presents a brief structure of all cases tested in this study, where effect of different factors, i.e., location of incident, percentage of information, percentage of trucks, different truck diversion probabilities (compared to passenger cars' diversion rate), different value of travel time (VOT), are taken into account.

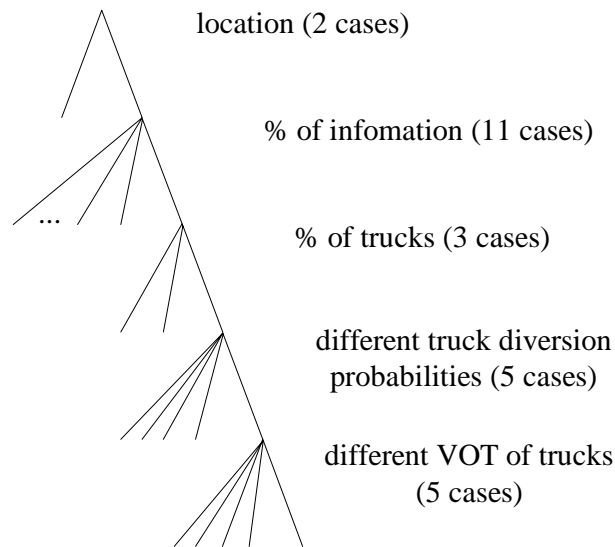


Figure 3. Structure of All Cases Tested in This Study

Three performance measures are used for the proposed traveler information evaluation process, i.e., Average Travel Time (ATT), Total Travel Cost (TTC), and V/C ratio. These measures directly represent the benefit of traveler information systems (but do not capture additional benefits of lowering schedule delays or vehicle and pollution costs).

## RESULTS

The road network and incident parameters used in the traffic modeling tool are:

- Free flow travel times in Route ABC, ADC, and DB are 40, 45, and 8 minutes, respectively;
- Free flow speed for each link is set to 60 miles per hour;
- Initial traffic flows in link AB, AD, DB, DC, and BC are 2500, 2000, 500, 1500, and 3000 vehicles per hour;
- Incident duration is 45 minutes;
- Incident reduces capacity 40%, but 60% of capacity remains;

- There are two types of incident locations, where travelers may or may not observe the incident-induced queue (see Road Network and Incident section for detail).

These settings are for demonstration purposes, and are realistic for an urban area, with alternate routes and incident information availability. These values can be changed in the tool in order to evaluate the benefits of ATIS expansions, requiring a distribution of annual incidents in the network.

### **Average Travel Time**

Figures 4 and 5 show the graphical representations of network average travel time (ATT) with different percentages of traffic information provided and truck flow. There are some interesting similarities and differences between two proposed situations, i.e., Set 1 – nobody can observe the incident-induced queue; and Set 2 – some travelers could observe the queue.

First, as shown in Figure 4, the overall trend in Set 1 scenarios is that the network ATT could be reduced by increasing the percentage of traffic information provided, which is as expected. Also there is an increase in network ATT with the increased percentage of truck flow. The effect of providing information, as opposed to the situation where nobody observes the incident-induced queue, shows the benefits of providing traffic information to travelers. For example, with 10% truck flow, providing 50% travelers with information could improve the network performance by 3.62% ATT. Table 5 shows the reduced rate of network ATT under different percentages of traffic information provided and truck flow, as compared to the base scenario (no traffic information provided). It is obvious that the benefit of providing information may be greater when the traffic contains more trucks, because truck traffic usually has greater impacts on the entire traffic flow than regular passenger cars, especially when incidents occur.

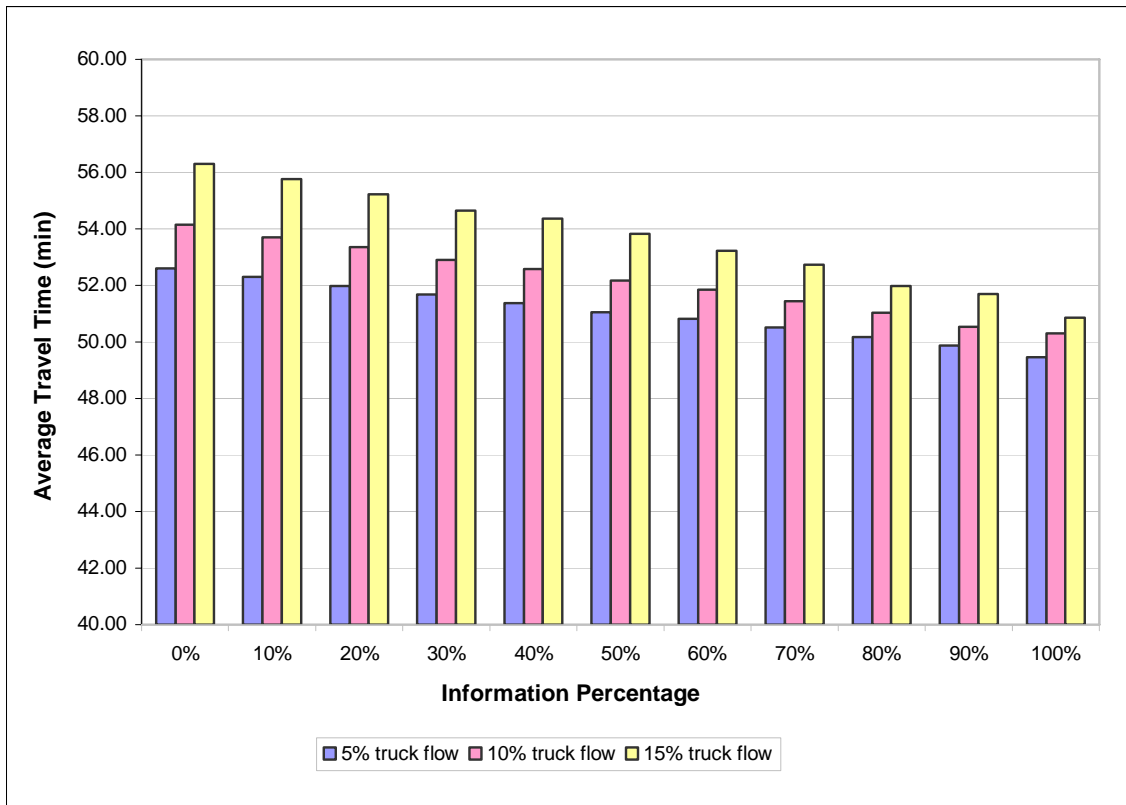


Figure 4. Average Travel Time for Set 1 Scenarios

Table 5. Reduced Rate of Average Travel Time for Set 1 Scenarios

Information Percent	5% truck flow	10% truck flow	15% truck flow
0%	0.00%	0.00%	0.00%
10%	0.58%	0.81%	0.97%
20%	1.16%	1.46%	1.92%
30%	1.76%	2.28%	2.95%
40%	2.32%	2.87%	3.45%
50%	2.95%	3.62%	4.40%
60%	3.39%	4.22%	5.48%
70%	3.96%	4.99%	6.36%
80%	4.59%	5.72%	7.67%
90%	5.18%	6.66%	8.17%
100%	5.94%	7.09%	9.67%

In Set 2 scenarios, the increased percentage of truck flow still is associated with an increase in network ATT (as shown in Figure 5). The trend of declining network ATT with an increasing percentage of information provided also remains as expected. However, the corresponding benefits of providing traffic information differ from Set 1 scenarios. Figure 6 shows that the decline rates of network ATT under Set 2 scenarios is far lower than the benefit

under Set 1 scenarios. With 15% truck flow, the effect of providing information to all travelers in Set 1 scenarios is about a 10% reduction in network ATT, compared with only about a 2.5% reduction in Set 2 scenarios. In addition, the difference in benefit of information among different percentages of trucks in traffic is weakened. Given hundred percent of travelers provided with information, the difference in network ATT reduced rate between 15% and 5% truck flow is 3.72% (9.67% – 5.94%) in set 1 scenarios; however, the difference in set 2 scenarios is just 1.20% (2.67%– 1.47%). These results are due to the fact that most travelers are very sensitive to traffic congestion, based on the behavioral model. When traffic delay can be observed, especially the incident-induced queue, travelers tend to use alternate routes to achieve shorter travel time to their destinations. As a result, the benefit of providing traffic information in this set of scenarios is not as notable as in Set 1 scenarios.

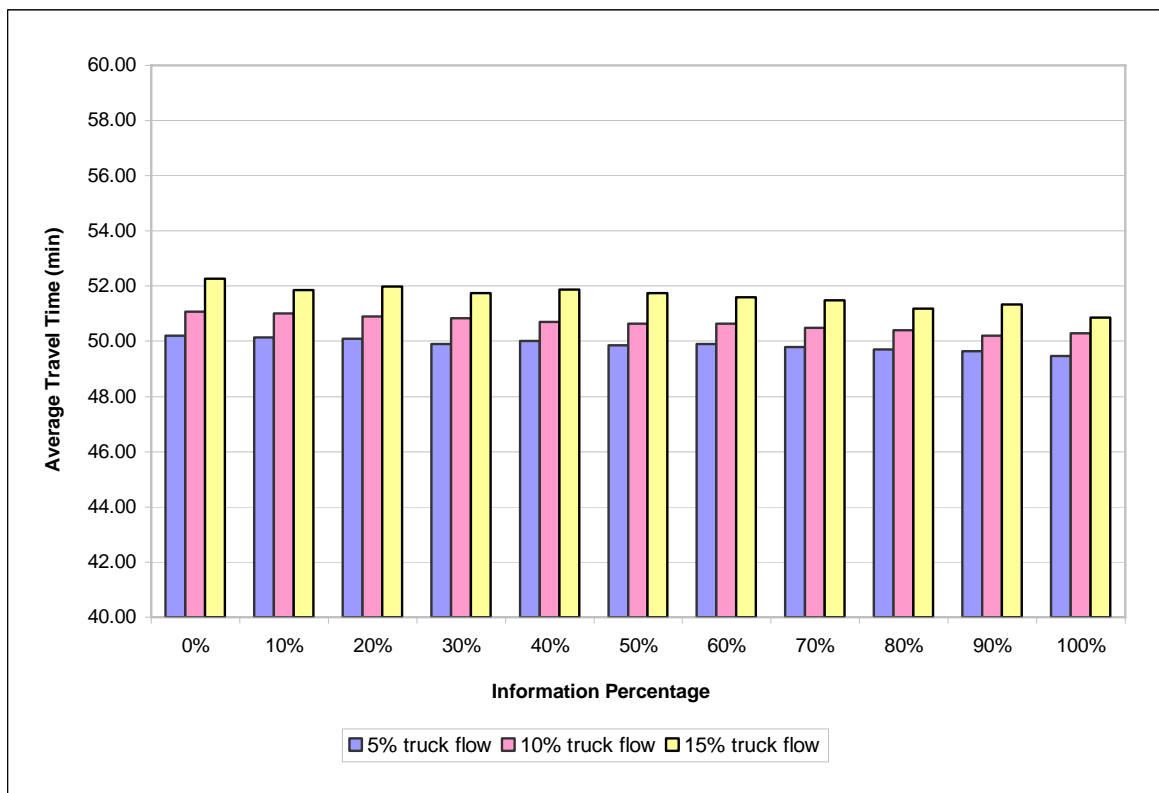


Figure 5. Average Travel Time for Set 2 Scenarios

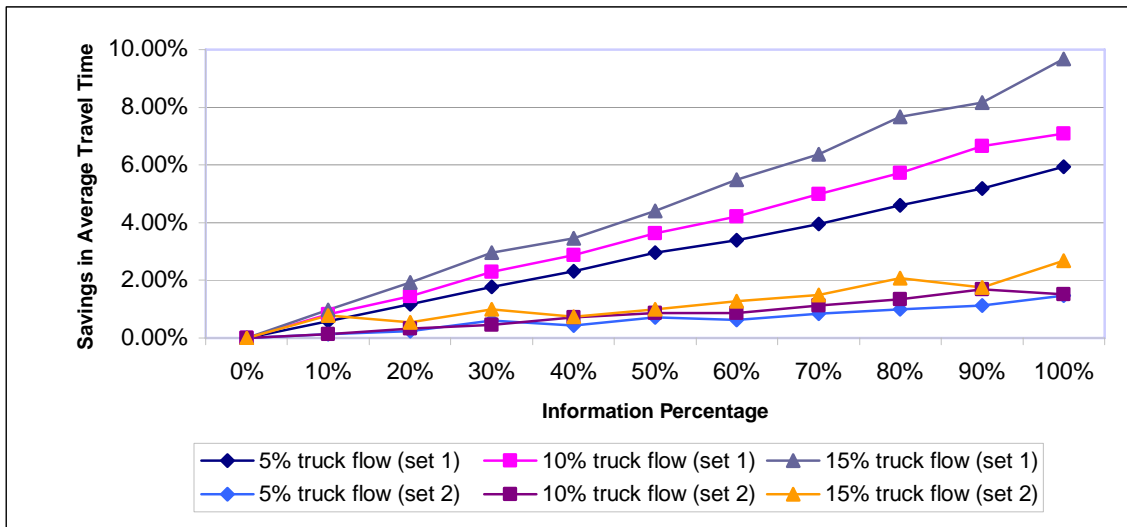


Figure 6. Benefit of Average Travel Time for Two Sets of Scenarios

### Total Travel Cost

Commercial carriers usually have a higher value of travel time (VOT) than motorists, and for demonstration we first assume the VOT for trucks is 5 times greater than that for motorists (this is partly based on literature showing that trucks delay costs are substantially higher than motorists) (35). With VOT for passenger cars equal to \$10 per hour per vehicle, analysis of total travel cost is illustrated in Figure 7. The figure shows remarkable benefits in total travel cost of providing traffic information in Set 1 scenarios. The slope of savings is rather steep in these scenarios. However, there are only flat increasing rates of savings shown for Set 2 scenarios, which indicate a lower effect of electronic traffic information on total travel cost in Set 2. We also find that, for traffic flows with higher truck percentages, the benefit of providing information is greater. Based on the literature as well as our study results, the benefit of providing traffic information under non-recurrent traffic congestion situation, especially to truck drivers, is greater, especially in the situations where travelers themselves cannot easily observe the queue ahead.



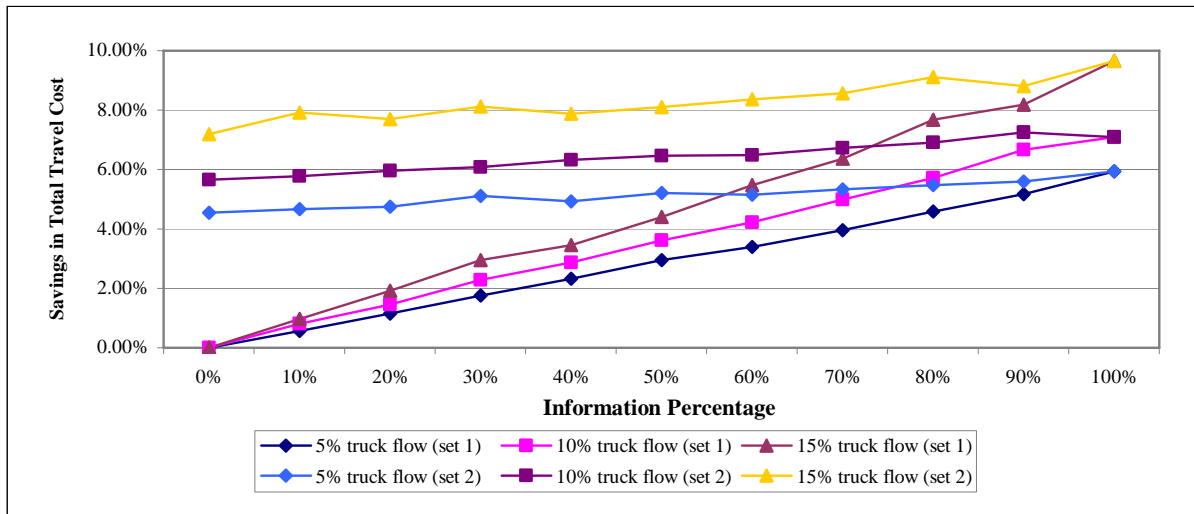


Figure 7. Benefit of Total Travel Cost for Two Sets of Scenarios

One reason for the lower effect of traffic information on the total travel cost in Set 2 scenarios is the restrictions coming from the traveler behavior model, i.e., high value of constant coefficient  $\beta_0$  in the behavioral model. This parameter indicates that the probability of drivers choosing the alternate route could be as high as 37%, if they can only observe the incident-induced congestion but not receive any electronic real-time traffic information, given a travel time difference between two routes equal to 20 minutes (shown in Table 2). However, based on existing literature, this rate may be on the high end. The model allows changing these parameters to suit local conditions and considerations.

### V/C Ratio

The relation between percentage of traffic information and the value of V/C ratio for each link are also studied. The V/C ratio on the alternate route is found to increase quickly with increasing traffic information provided to travelers, e.g., 0.45 with 0% information but 0.73 with 100% information (for link AD under Set 1 scenarios with 5% truck flow). This result indicates that broadcast real-time information can quickly congest alternate routes, which need to be monitored; in addition, traveler information can be provided (e.g., through HAR (Highway Advisory Radio) or CMS) to help users return to the major route downstream of congestion.

## Sensitivity Analysis

Sensitivity analysis is performed to ascertain how the given model output depends upon the input parameters, i.e., different diversion probability of commercial carriers (trucks) from that of motorists (cars), as well as the different value of travel time of trucks from that of cars.

### *For Different Truck Diversion Probability*

Five categories of truck diversion probability, comparing to car diversion rate, are assumed, which are 0%, 25%, 50%, 75%, and 100%. 0% means there is no truck that is allowed to divert to alternative route due to its physical characteristics; and 100% means trucks have the exact same travel behavior in terms of their diversion rate as passenger cars. Other parameters in the model are set to their median value, i.e., VOT for trucks is 5 times that for cars, and truck percentage in the traffic flow equals to 10%.

Figure 8 shows the differences in traffic information benefits in terms of average travel time with different diversion probabilities of commercial vehicles. We observe that, fixing the truck diversion probability, the savings in ATT increases with the percentage of traffic information availability. Moreover, since in scenario 1 (set 1) people could not observe incident-induced congestion, the marginal benefit of providing traffic information is larger than in scenario 2 (set 2), where people could observe the congestion. Hence in Figure 8, as expected, the ATT curves for scenario 1 have larger “slope” than that for scenario 2.

For scenario 1, savings in average travel time of lower truck diversion probability tend to be less. The reason for this is because fewer trucks choose to divert from the incident scene, which results in more trucks involved in incident-induced congestion. However, for scenario 2, the effects of traveler information (savings in ATT) do not seem to have a clear relationship with truck diversion probabilities. Under a certain percentage of traveler information, savings in ATT may or may not increase as the diversion percentage of trucks increases. On the one hand, this ambiguous ordering result indicate that if travelers could observe traffic incident by themselves, then the diversion probability of trucks has little influence on total ATT because the diverted passenger cars have already induce significant savings in total ATT (note these passenger cars can also observe the incident); on the other hand, from statistical perspective, this result is largely due to the high value of constant coefficient  $\beta_0$  in the behavioral model. The high value

of constant coefficient  $\beta_0$  dominates the effects of independent variables (travel information availability and travel time difference), whose effects are relatively small.

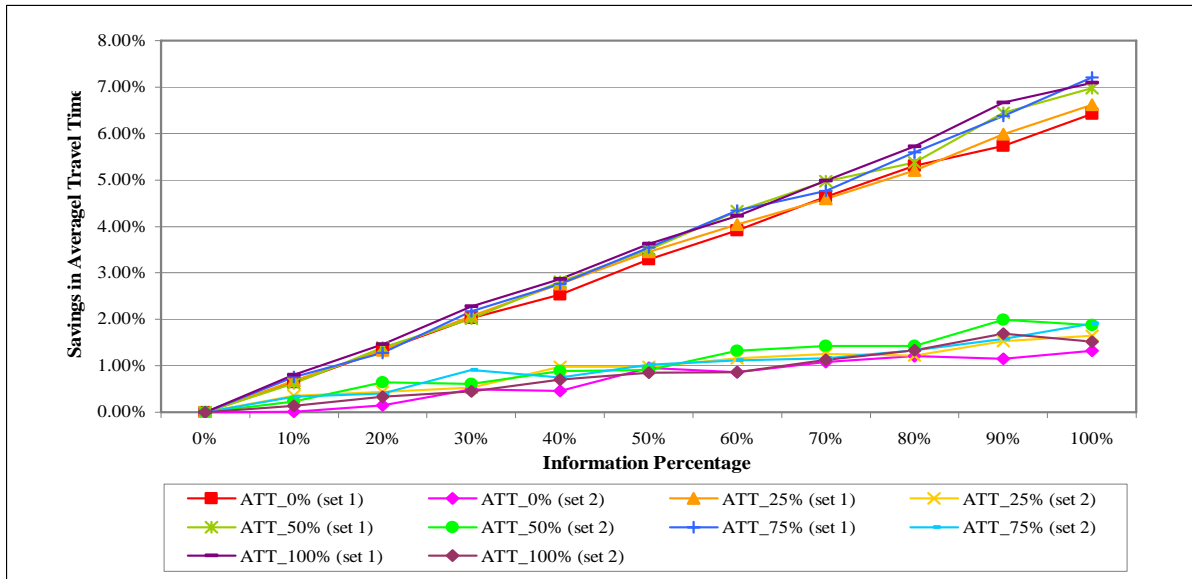


Figure 8. Benefit of Average Travel Time for Different Truck Diversion Probability

Figure 9 shows the savings in ATT under different truck diversion probabilities. Note that the percentages on the vertical axis here represent the savings in percentage as compared to the base case (no traffic information is provided and drivers can not observe the incident), and the horizontal axis represents the percentage of travelers who receive traffic information. The interesting, yet expected findings here are three fold. First, for both scenarios (set 1 & 2), fixing the percentage of traffic information availability, savings in total travel cost increase with the truck diversion probability. Second, for both scenarios (set 1 & 2), fixing the truck diversion probability, savings in total travel cost increase with the percentage of traffic information availability, which follows the similar pattern as we see above. As expected, for set 1 (users can't observe traffic congestion), percentages of savings in ATT increase from 0 to 5~6% if traffic information availability increases from 0 to 100%, while for set 2 (users can observe traffic congestion), percentage of savings does not vary too much (only increases by 1%) if one increases traffic information availability from 0 to 100%. Third, fixing the truck diversion probability, savings in total travel cost are higher when users can observe the incident (set 2) than when they can not (set 1). Furthermore, this gap decreases as the percentage of traffic

information availability increases and almost vanishes when all travelers can get traffic information. In general, the more information available to travelers, the larger savings in total travel cost. Hence, an important implication here is that guiding commercial carriers' route choice with dynamic traffic information may bring noticeable benefits, especially under incident situation when travelers could not observe the congestion.

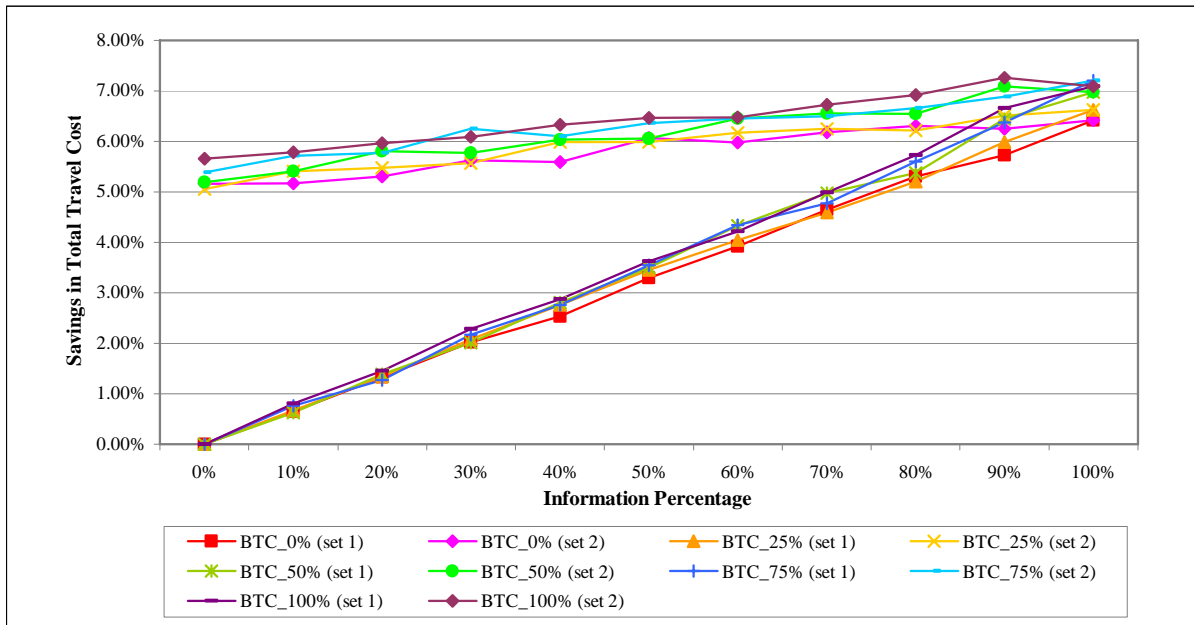


Figure 9. Benefit of Total Travel Cost for Different Truck Diversion Probability

*For Different VOT of Truck*

Five different truck VOTs are tested in the study, i.e., 1, 3, 5, 7, and 10 times of passenger cars, while holding other parameters equal to their median value, i.e., truck diversion probability is one-half of cars, and truck percentage in the traffic flow equals to 10%. Recall that the VOT of passenger cars is around \$10 per hour per vehicle in many research studies. According to a ongoing study by some researchers at the University of North Carolina at Chapel Hill, the VOT of commercial vehicles is around \$100 per hour per vehicle and highly variable, depending on types of goods, destination constraints, and a host of other factors. So the values of truck VOTs we take in this study are reasonable and tend to be conservative.

Effects of traveler information on different VOT of trucks are shown in Figure 10, where the vertical axis represents the percentages of savings in total travel cost of different cases compared to the base case (no traffic information is provided and drivers can not observe the

incident, but the truck VOT takes the same value as the case to be compared). The horizontal axis represents the percentage of travelers who receive traffic information.

One striking result here is that the percentage of savings in total travel cost decreases with the increasing truck VOT for both scenarios. For instance, suppose that travelers can observe traffic congestion and 50% of the travelers are exposed to the detailed traffic information, e.g. the travel time difference for making diversion decisions. Then one expects to save around 6.06% of total travel cost if truck VOT is \$10 per vehicle per hour, but only save about 4.93% of total travel cost if truck VOT is \$70 per vehicle per hour. One possible reason for this would be that although the relative savings in total travel cost as compared to the base cases increase with truck VOT, the total travel costs of base cases also increase with truck VOT and of a larger magnitude. The increments of total travel cost thus overwhelm the savings of total travel cost; hence the percentage of savings decreases with the increasing truck VOT.

Another interesting, yet intuitive finding is that the percentage of savings in total travel cost when travelers could not observe congestion are smaller than when travelers could, but the gap decreases with the percentage of information availability. Not surprisingly, we also would expect that if travelers could observe traffic congestion, then the marginal savings in total travel cost by increasing traffic information availability is much smaller than if travelers could not, which explains why the slopes of saving curves for cases in set 2 are much “smaller” than set 1. One could see that compared to travelers with lower VOT, the travel cost (due to unexpected travel delay) of road users with higher VOT is generally not reflected in terms of percentage of savings in TTC, especially when travelers themselves could observe congestion (set 2). Therefore, not only by providing real time traffic information, we should also develop more countermeasures, if necessary, to help these road users, i.e. commercial carriers (trucks) with high VOT, to increase their saving percentage in TTC. Note that in this set of experiments, the probability of truck diversion is fixed to half of passenger cars. However, if the countermeasure we take would induce more trucks to divert to the alternate route (to save time), then one may see even greater benefits. The methodology to study this is essentially the same to what we employed here. Instead of assuming the probability of truck diversion to be half of passenger cars, we should use some different diversion probabilities.

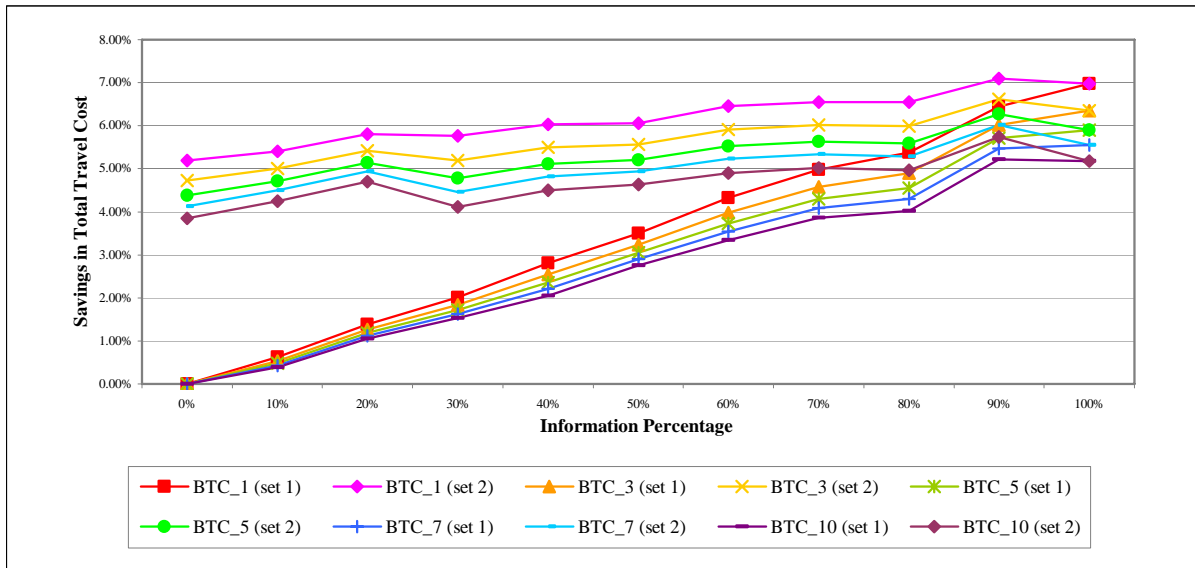


Figure 10. Benefit of Total Travel Cost for Different VOT of Truck

**CONCLUSIONS**

This research develops a tool for traveler information evaluation while accounting for different types of users. The evaluation tool builds on a macroscopic traffic modeling tool, adds in a traveler behavior model based on a real data field study, and demonstrates the effect of traveler information under different user and vehicle features. The benefits of providing information in incident situations are measured in terms of network average travel time changes, total travel cost changes, and V/C ratio changes. The proposed tool provides transportation planners and engineers with decision support for evaluating and expanding ATIS coverage. Sensitivity analysis was used to ascertain how the given model output depends upon the input parameters, i.e., the study tested different diversion probabilities for commercial carriers (trucks) vis-à-vis motorists (cars), as well as the different values of travel time for trucks versus passenger cars.

Several new aspects of traveler behavior and network performance have been addressed in this study. The most important one is that the tool used in the study can perform ATIS evaluation accounting for different user/vehicle features. It captures the different effects that motorists (cars) and commercial carriers (trucks) have on traffic flow as well as the network performance. Furthermore, it highlights the fact that motorists and commercial carriers have different travel behavior that will result in different diversion choices when facing incident-

induced congestion. By using a behavioral choice model, the study captures the different effects of traveler information in different users.

We used a simple incident scenario to demonstrate the workings of the tool and how various assumptions can be changed to suit local conditions. The important and interesting findings are:

- Substantial network performance benefits can be obtained from disseminating travel information. Network average travel time and total travel cost can be reduced (up to about 10%) by increasing the percentage of traffic information provided, which shows the benefits of providing travelers traffic information on incident-induced congestion.
- Average travel time and total travel cost increase with an increased percentage of truck flow, because truck traffic has a greater impact on traffic flow than passenger cars. There is a demand for broadcasting real-time traffic information under incident-induced congestion situations, as both individual travelers and commercial users benefit.
- The benefits of electronic information are lower if travelers can observe the incident-induced congestion.
- The V/C ratio on alternate routes quickly increases with an increase in traffic information provided to travelers. This indicates the need for providing and updating dynamic traffic information for the transportation system, including traffic conditions on alternate routes.
- The proposed model is sensitive to different truck diversion rates as well as different VOT of trucks. For instance, lower truck diversion rates would result in evidently less benefit in terms of network performance. At the same time, higher VOT of truck would induce smaller percentage of savings in total travel cost.

Further research is needed. Specifically, other performance measures that include late arrival at destination, vehicle costs, and emissions, late incoming/outgoing deliveries, and the costs of keeping additional inventory by businesses, should capture additional benefits of information. Indeed the benefits of information presented are on the conservative side, given that we use a subset of performance measures. While the route diversion of motorists has been studied, behavior of truck drivers is not well researched, where we assume different diversion probability of trucks is half of that of cars. It will be important to understand information needs of truck drivers and whether customizing traffic information to these users can help them improve on-time performance and stimulate economic development.

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