Factors Influencing Commuters' En Route Diversion Behavior in Response to Delay

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An understanding of drivers' en route decisions may help design strategies for ameliorating traffic congestion. A survey of downtown Chicago automobile commuters was conducted to investigate en route diversion in response to incident-induced congestion. The effects of factors such as source of congestion information (radio traffic reports versus observation), driver and trip characteristics, route attributes, and environmental conditions on driver response to delay were explored. En route diversion behavior was found to be influenced by source of traffic information, expected length of delay, regular travel time on the usual route, number of alternate routes used recently, anticipated congestion level on the alternate route, gender of the driver, residential location, self-evaluation statements about risk behavior (personality), and stated preferences about diverting. The results show that real-time traffic information broadcasts provide a basis for en route diversion decisions. Further, length of delay and perception of traffic congestion on the alternate route also influence such decisions. Short-term improvements in real-time traffic information should focus on disseminating information about length of delay due to incidents and the congestion levels on the alternate routes surrounding the incident. This action requires monitoring traffic conditions on the alternate routes along major roadways. Providing clearer information on delays and congestion will help drivers make more informed route selection decisions.

Traffic congestion occurs when the vehicles using a roadway impede each other's progress. The consequences of congestion include delays, accidents, excessive fuel consumption, air pollution, and driver frustration. One way to ameliorate traffic congestion is through demand management strategies designed to modify driver behavior by encouraging drivers to change modes, routes, and departure times.

Congestion can be incident induced or recurring. Incident-induced congestion may be caused by accidents, vehicle disabilities, short-term maintenance activities, weather, and so on. Recurring congestion is caused by an increase in demand during rush hours. McDermott (*1*) has estimated that each causes about half of the congestion on Chicago area freeways. The congestion problem becomes acute when incident-induced congestion occurs during recurring congestion (peak period).

One demand management strategy used in larger cities is the collection, processing, and dissemination of near real-time information about traffic conditions on key highway links. This information usually includes qualitative or quantitative descriptions of congestion, reports of incidents, and, in the Chicago area, estimates of point-to-point travel times. Broadcast traffic information in Chicago is relatively sophisticated.

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Real-time traffic information on the downtown-oriented freeways is gathered with a network of loop detectors maintained by the Illinois Department of Transportation (IDOT). Many radio stations compete for the drive-time market by providing rush-hour traffic reports: some use IDOT information alone, and others buy traffic information from specialty firms that mix reports from ground and aerial observers with IDOT information. A few radio stations supplement these sources with their own networks of observers.

Real-time traffic information is intended to help travelers make better choices of modes, departure times, and routes, as well as to reduce their en route anxiety. Considerable public and private resources are devoted to collecting and disseminating this information, so it is important to understand its impact on motorists. As congestion grows and there are fewer capital-intensive options to ameliorate it, the potential importance of near real-time traffic information grows. The worldwide interest in the intelligent vehicle-highway system (IVHS) is founded on assumptions about driver responses to such information (*2*).

An understanding of drivers' en route decisions is important for designing congestion-reduction strategies, particularly the IVHS. Relatively little is known about such decisions, and this study was conducted to contribute to that body of knowledge, specifically to investigate factors influencing en route response to incident-induced congestion. The effects of real-time traffic information along with factors such as driver, trip, and roadway characteristics were evaluated.

Several researchers have found that a significant number of drivers divert in response to delay on their preferred route (*3–7*). Therefore, delay was selected as the criterion for investigating driver response to incident-induced congestion. It was decided to interview downtown Chicago automobile commuters because the Chicago area traffic monitoring system is downtown focused and because downtown automobile commuters regularly experience congestion.

CONCEPTUAL FRAMEWORK

It was hypothesized that drivers are influenced by real-time traffic information, such as traffic reports, and by the following factors (see Figure 1):

- Incident characteristics, such as length of delay;
- Trip characteristics, such as trip origin and destination and availability of alternate routes;
- Attributes of preferred and alternate routes, such as travel time and scenery;

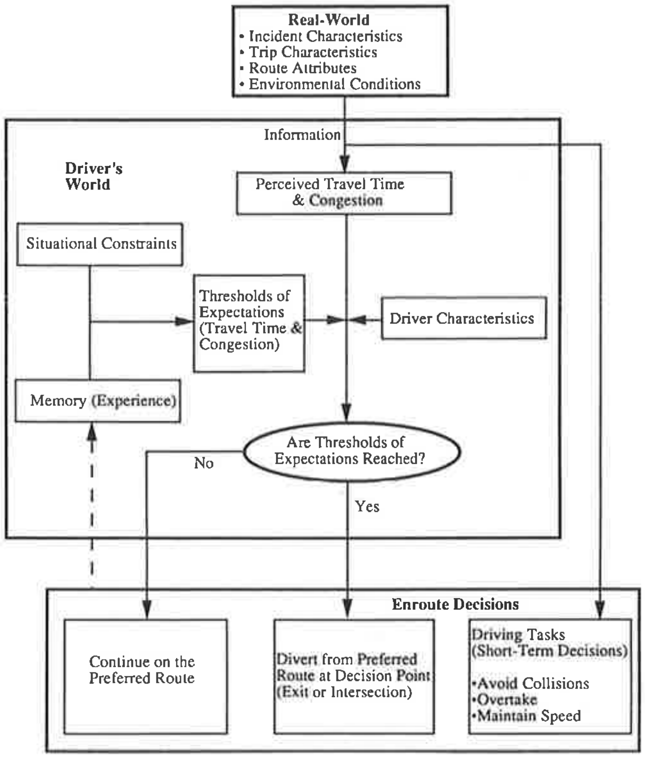

FIGURE 1 Conceptualization of en route decision-making process.

- Environmental conditions, such as weather;
- Driver characteristics, such as age, gender, and personality;
- Work rules, such as flexibility in work arrival time and type of work; and
- Situational constraints, such as remaining trip length.

Drivers perceive information through direct contact with the environment; in response they perform driving tasks; that is, short-term decisions such as overtaking and maintaining speed. Commuters making regular work trips compare the perceived travel time and congestion to their expectations. If thresholds of their expectations are reached (when there are large differences between perceptions and expectations, e.g., when there is a major delay), the driver experiences frustration and may be prompted to make a diversion decision. The thresholds of expectations may vary for the same person depending on the situation and, of course, may vary among individuals. In some cases, a driver may be frustrated with a delay situation but continue on the selected route. Although it may be impossible to measure time and congestion thresholds, revealed behavior can indicate if the thresholds were reached: if a person diverts in response to delay, the individual's time threshold was reached.

RELEVANT LITERATURE

Diversion behavior of drivers has been investigated primarily in the context of short-term maintenance operations and special events. The method used can be categorized as (a) the stated preference approach, (b) the revealed (or reported) preference approach, and (c) the field study approach. The stated preference approach analyzes driver predictions of their behavior in response to hypothetical scenarios; for example, respondents might be asked if they would divert in response to a particular delay. The revealed preference approach analyzes drivers behavior in real-life situations on the basis of respondents' reports about previous actions; for example, respondents might be asked if they diverted in a specific case. The field study approach analyzes driver behavior through field observations of drivers, for example, observation of actual diversion behavior in response to specific incidents.

Self-predicted behavior of respondents may be quite different from their revealed behavior, and thus it is not uncommon to find differences between stated and revealed behavior. The revealed preference approach was used, although stated preferences were used to a lesser extent for added insights and for comparison with revealed preferences.

Table 1 presents a summary of factors that influence diversion behavior, along with the research approach used in the study. Overall, the factors found to induce diversion were traffic information (*3,4,7–14,18,20,21*), longer travel time on the preferred route (*5–7,11*), congestion and delay on the preferred route (*3–6,8–11,13,18,19*), and familiarity with the alternate route (*10,11*). Factors found to inhibit diversion were longer travel times on the alternate route (*5,6,11,18*), expected congestion and delay on the alternate route (*8,11,18*), and traffic stops on the alternate route (*5,18*). Young, male, and unmarried drivers had a higher inclination to switch routes (*6,7*).

Using the stated preference approach, Huchingson and Dudek (*4*) and Huchingson et al. (*9*) found the relationship between delay and diversion to resemble an S-shaped curve, with few drivers expressing willingness to divert in response to minor delays and all but about 5 percent expressing willingness to divert in response to 30- to 60-min delays. In contrast, researchers using the revealed preference approach have found that a large portion of the driver population did not divert at all. For example, Huchingson et al. (*11*) found that only 60 percent of commuters in Dallas had taken one or more alternate routes; Daniels et al. (*12*) found that 36 percent of Chicago drivers surveyed had never diverted. Thus, drivers may express willingness to divert in hypothetical situations, but their actual diversions may be considerably less, perhaps influenced by a variety of situational variables.

Huchingson and Dudek (*4*) used the stated preference approach and found that the median value of delay for diversion was 15 to 20 min for various groups from different locations in the United States. A similar study in Houston found the median value of delay for diversion to be 5 to 6 min, which might be due to the availability of a convenient service road as an alternate route (*9*). Haselkorn et al. (*10*) found that the averages of length of delay before diverting vary between 13.5 and 27.4 min.

Several researchers using the revealed preference approach have found that a significant number of drivers divert from their preferred route. For example, Heathington et al. (*8*) found that on the average commuters diverted 23 percent of the time due to congestion on their preferred route. Huchingson et al. (*11*) found that 27 percent of the respondents diverted in response to incidents (which they were asked to recall), whereas 69 percent continued on their preferred route.

TABLE 1 SUMMARY OF FACTORS FOUND TO INFLUENCE DIVERSION BEHAVIOR (SELECTED STUDIES)

Author(s)	Traffic Information	Travel Time Preferred Route	Travel Time Alternate Route	Delay on Preferred Route	Congestion on Preferred Route	Congestion on Alternate Route	Familiarity with Alternate Route	Traffic Stops on the Routes	Location Sample Size & Methodology [1]
Heathington, et al. (*8*)	+			+		-			Chicago, IL. N=732. SP, RP
Dudek, et al. (*3*)	+				+				Houston & Dallas, TX. N=505. RP
Haefner & Dickinson (*30*)		+							Baltimore-Washington. N=? RP
Daniels, et al. (*12*)	+								Chicago, IL. N=732. RP
Huchingson, et al. (*11*)	+	+	-	+	+	-	+		Dallas, TX. N=202, 215. RP
Richards, et al. (*18*)	+		-	+		-	+ -	-	Dallas, TX. N=480. RP, FS
Turner, et al. (*21*)	+								Chicago, IL. FS
Dudek, et al. (*14*)	+								Dallas, TX. FS
Huchingson & Dudek (*4*)	+			+					Multistate. N= 240, 184, 40. SP
Dudek, et al. (*19*)	?			+	+				San Antonio, TX. FS
Roper, et al. (*20*)	+								Los Angeles, CA. FS
Huchingson, et al. (*9*)	+			+					Houston, TX. N=843. SP
Shirazi, et al. (*13*)	+				+				Los Angeles, CA. N=400. RP
Stephanedes, et al. (*5*)		+	-	+				-	Twin Cities, MN. N=105, 195. RP
Mannering (*6*)		+	-		+				Seattle, WA. N=117. RP
Haselkorn, et al. (*10*)	+			+	+		+		Seattle, WA. N=3893. RP, SP
Mahmassani, et al. (*7*)	+	+ -							Austin, TX. N=372. RP

\+ = Induces Diversion; - = Inhibits Diversion

[1] SP=Stated Preference approach (hypothetical scenarios).
RP=Revealed Preference approach (real-life situations described by respondents)
FS=Field Study approach (observation of driver behavior by researchers)

Shirazi et al. (*13*) found that 40 percent of the commuters in Los Angeles diverted on their way to work, and 14 percent of the respondents diverted either very often or often.

Traffic information has been found to influence diversion. Heathington et al. (*8*) found that driving patterns of frequent diverters were influenced slightly more by traffic reports than by visual observation. Mahmassani et al. (*7*, p. 11) found that drivers who generally listen to radio traffic reports have a greater propensity to switch routes. Daniels et al. (*12*) found that the average frequency of diversion for Chicago drivers was 16 to 27 percent for observed congestion and 17 to 35 percent for traffic reports. Thirty percent of the drivers in the Sharazi et al. (*13*) study said that radio traffic reports help them in their decision to divert.

For content and format of real-time traffic information, guidelines for highway advisory radio messages have been developed (*14,15*). Moreover, Dudek et al. (*16*) found from a laboratory study that drivers preferred terse messages rather than conversational style. Unfamiliar drivers going to a special event were more likely to divert in response to highway advisory radio diversion messages than were familiar drivers (*17*). Generally, studies that have used the revealed preference approach indicate that information either in the form of diversion advice or travel times and congestion can induce drivers to divert.

Field studies of diversion behavior have shown mixed results. Dudek et al. (*19*) evaluated the effect of changeable message signs on diversion in San Antonio, Texas, and could not find statistical evidence for increased diversion due to messages displayed under incident conditions. Roper et al. (*20*) found that drivers in Los Angeles were successfully diverted from a busy freeway during repairs through a comprehensive public management campaign and the use of changeable message signs during the closure. Diversion messages developed in laboratory studies were effective in diverting freeway traffic going to special events (*14,18*). Turner et al. (*21*) also found evidence of increased diversions due to changeable message signs; however, the findings were not based on statistically sound data bases for comparisons. Overall, field studies indicate that drivers can be successfully diverted to alternate routes during special events through diversion messages, but there is not enough evidence to suggest that drivers can be successfully diverted during incidents.

Several researchers have found that drivers were more likely to divert to familiar routes (*10,11,18*), suggesting that cognitive maps of drivers may influence their diversion behavior. Cognitive maps are stored information about the relative location of objects in the physical environment, and they have been linked to lifestyle, age, stage in family life cycle, and social class (*22*). The state of an individual's cognitive map indicates the level of familiarity with the network and route alternatives. The number of alternate routes used by a driver was chosen as a proxy for cognitive maps. Freundschuh (*23*) provides a review of cognitive maps in the context of developing IVHS technology.

METHODOLOGY

Sampling

The target population for empirical work consisted of automobile drivers who made repeated trips during which broadcast traffic information was available to them. Drivers who made regular trips were of interest because it is easier for the respondents and the researchers to identify behavior patterns, and it is probably these drivers who experience the worst congestion on a regular basis. The importance of the availability of traffic information is obvious, because it is the effect of this factor that was to be explored.

Due to the radial orientation of the freeway network in Chicago and the availability of several alternate routes, it was decided to sample work trip drivers destined to the central business district (CBD). These travelers were intercepted at a sample of downtown parking garages during rush hours (7:00 to 10:00 a.m.). Mail-back questionnaires were distributed to commuters as they walked out of garages in the morning during April 1990. A total of 700 questionnaires was received, representing a response rate of 33 percent.

Self-selection bias is inherent in surveys of this type. Some degree of bias may be a reasonable price to pay for obtaining insights into real-world diversion behavior and for refining hypotheses. To check for obvious biases, the socioeconomic attributes and trip characteristics of this sample were compared with those of other samples of commuters who drove to downtown Chicago (*24*). This sample compared reasonably well with similar samples of commuters in the Chicago area, and it was consistent with expectations about downtown Chicago commuters (*25*). There were no indications of substantial distortions in the socioeconomic characteristics of the respondents, which does not preclude the possibility of self-selection bias in other dimensions (e.g., behavioral patterns, personalities, and cognitive maps).

Instrument Design

Driver response to a specific, recent delay experience was investigated as opposed to delays in general because this factor was expected to produce more meaningful results. First, the respondents were asked if they knew about an en route delay longer than 10 min on their way to or from work during the past 6 months. There was a possibility of memory loss or distortion of responses to the delay experience because of the length of this time interval. However, the data showed that, among the 62.5 percent of respondents who knew about a delay longer than 10 min, 77.5 percent had experienced this delay within the past 2 months. Therefore, the influence of memory loss and distortion seems small for a majority of the respondents. The survey then asked about the details of the delay experience, for example, how and when drivers received the delay information. At the end of the section on delays, the survey asked if respondents diverted to an alternate route because of the delay.

The usual and alternate routes were defined as substantially different to avoid the complexity of dealing with a large number of small variations in the route of travel. Furthermore, there is no evidence in the literature to indicate that drivers consider a large number of overlapping alternatives when selecting routes. Stephanedes et al. (*5*) found that less than 3 percent of the commuters in Minneapolis–St. Paul considered more than two alternatives, and, if they did, it was under unusual circumstances such as a blizzard. It was explained to the respondents through an illustration that the predominant roadway on the alternate route should be different from that on the usual route. To further clarify the definition, respondents were given an example in which a freeway was the usual route and a parallel arterial street was the alternate.

The Chicago area experienced a severe snowstorm on February 14, 1990 (known as the Valentine's Day snowstorm), with disastrous consequences for automobile commuters. Results of this study showed that the average travel time on the trip home was 163 min instead of 46 min under normal conditions. There was concern that experiences on the day of this blizzard might distort responses to the survey. Because the objective was to investigate delays caused by day-to-day congestion and not delays due to weather extremes, the questionnaire included a separate section on the blizzard (results not reported here) to separate routine experiences from unique circumstances.

OVERVIEW OF RESPONSES

A profile of the respondents' socioeconomic attributes is presented in Table 2. The sample represents a stable, upper income, well-educated, and well-established group. One of the objectives was to sample regular peak-period automobile commuters, and Table 3 indicates that this goal was accomplished. Most respondents traveled regularly to downtown Chicago; about 86 percent had traveled more than 10 times to downtown Chicago during the past month.

Most respondents (93 percent) started their work between 7:30 and 9:00 a.m. The median work start time was 8:30 a.m. More than 90 percent of the respondents could not arrive more than 1 hr late "without it mattering much." The mode and median for arrival time flexibility were both 15 min. Most

TABLE 2 SUMMARY OF RESPONDENTS' SOCIOECONOMIC ATTRIBUTES

Sample Attributes		Frequency %	Sample Attributes		Frequency %
Age	20-29 Years	23.6	**Household Size**	1 Person	16.6
	39-39 Years	33.0		2 persons	35.5
	40-49 Years	29.7		3 persons	19.5
	50-65 Years	12.5		4 persons or more	28.4
	65 Plus Years	1.2			
Gender	Male	54.3	**Area of Residence**	Suburbs	52.7
	Female	45.7		Chicago	47.3
Occupation	Managerial/Business owner	23.7	**Time at Present Job Location**	Up to 1 Year	13.9
	Clerical	7.7		Between 1-2 Years	19.1
	Professional/Technical	54.5		Between 3-5 Years	23.3
	Sales	9.2		Between 6-10 Years	17.5
	Other	4.9		More than 10 Years	26.2
Education	High School	4.6	**Time at Present Home Location**	Up to 1 Year	11.5
	Vocation/Technical School	2.0		Between 1-2 Years	21.2
	Some College	19.4		Between 3-5 Years	24.0
	Graduated College	34.1		Between 6-10 Years	13.9
	Post Graduate Work	39.9		More than 10 Years	29.4
Income	Up to $20,000	4.3			
	$20,000-$40,000	33.1			
	$40,000-$60,000	26.3			
	$60,000-$80,000	14.0			
	$80,000-$100,000	6.6			
	$100,000 Plus	15.7			

Percentages do not consider missing data. Total Sample Size=700.

TABLE 3 SUMMARY OF RESPONDENTS' TRIP CHARACTERISTICS

Sample Attributes		Frequency %
Number of downtown Trips During Past Month	Up to 10 Times	14.1
	11-15 Times	10.0
	16-20 Times	20.2
	21 Times or More	55.7
Work Start Time	Up to 8:00 AM	39.9
	Between 8:01-8:30 AM	36.8
	After 8:30 AM	23.3
Flexibility in Work Start Time	0-15 Minutes	53.2
	15-60 Minutes	38.1
	More than 60 Minutes	8.7
Car Occupancy	1 Person	67.6
	2 Persons	26.8
	3 or More Persons	5.6
When Route is Chosen	Before Getting in Car	74.0
	After Getting in Car	26.0
Years Used Usual Route	Up to 1 Year	20.2
	Between 1-4 Years	49.4
	More than 4 Years	30.4
Number of Alternate Routes Used	None	7.8
	1 Route	28.0
	2 Routes	32.7
	3 Routes	18.1
	4 or More Routes	13.4

Percentages do not consider missing data. Total Sample Size=700.

respondents chose their route before getting in their cars. Close to 80 percent had used their route for more than a year, although not without variation. Most respondents (63.2 percent) had taken two or more substantially different alternate routes between home and work. The average travel time to work was 42.6 min and that from work was 46.1 min. As expected, the best alternate route took longer on the average (49.8 min).

About 62 percent of the respondents experienced en route delays during the past 6 months (see Table 4). Nearly 85 percent expected the delay to add between 10 and 30 min to their work trip. A majority of the respondents (60.8 percent) described their delay experience on the home-to-work trip. Forty-three percent said they received the information about delays through radio traffic reports. More than 42 percent took an alternate route in response to en route delays. Because the alternate route was defined as substantially different from the preferred route, the diversion decision represents a major behavioral change.

To assess the influence of driver personality on en route diversion, 14 self-assessment questions were used. Some of these were borrowed from the psychology literature, as well as from other work that explored the travel behavior relationship (*26*). Several questions developed in this study were added, focused specifically on behaviors likely to describe route choice.

Several personality factors were identified using factor analysis. Only the most relevant factor, termed "adventure and discovery," is reported here. On the basis of the responses to the statements presented in Table 5, this factor represents respondents' propensity toward risk and exploration. It was expected that drivers who are risk prone and inclined toward exploration may be more willing to divert from their preferred route. The sums of respondents' scores on these statements were used to model diversion behavior.

Stated preferences of drivers about diversion were investigated. This appraoch was intended to enrich the perspective on diversion behavior and compare the responses with findings from the revealed preference approach. The respondents gave their preferences about diversion in hypothetical situations, and the frequencies are presented in Table 6. The sums of scores on these statements, which represent a driver's propensity to divert, were used to model diversion behavior.

TABLE 4 SUMMARY OF RESPONDENTS' DELAY EXPERIENCE

Questions	Frequency %	Number of respondents
Do you know of a traffic "delay" longer than 10 minutes after you got on your "usual" route during the past six (6) months?		
Yes (Experienced Delay)	62.5	437
No	37.5	262
How Long Ago did this happen?		
Less Than 1 Month	59.7	258
1-2 Months	17.8	77
2-3 Months	12.0	52
3-4 Months	5.6	24
More Than 4 Months	4.9	21
How much time did you expect the "delay" to add to your trip?		
10-20 Minutes	57.6	250
21-30 Minutes	27.0	117
31-40 Minutes	9.9	43
41-50 Minutes	3.9	17
More Than 50 Minutes	1.6	7
When you got the information about the "delay" were you on your way from:		
Home to Work	60.8	261
Work to Home	39.2	168
What was the weather like when you got the information on the "delay?"		
Clear	41.8	180
Cloudy and Dry	20.8	90
Rainy/Light Snow	35.3	152
Blizzard/Storm	2.1	9
How did you get the information on the "delay?"		
Radio Traffic Reports on Congestion Ahead	43.0	187
Your Own Observation of Unusually Heavy Congestion	55.4	241
Don't Recall	0.7	3
Other	0.9	4
Did you take an alternate route after getting the information on the "delay" on your usual route?		
Took Alternate Route	42.5	185
Continued on Usual Route	57.5	250

TABLE 5 ADVENTURE AND DISCOVERY FACTOR OF DRIVER PERSONALITY

Statement of the Question	Source of the Statement	Average Score
I like discovering new routes to get someplace	Modified from Ergun (*26*)	2.05
I sometimes do things just to see if I can	Ergun (*26*)	2.14
I am willing to take risks to avoid traffic delays	Modified from Ergun (*26*)	2.28
I like exploring new places	Modified from Ergun (*26*)	2.81
I am not afraid of getting lost in the Chicago area		2.89
I would rather take a little longer to use a route I know well		2.27

Responses coded as: 0=strongly disagree, 1=disagree, 2=neutral, 3=agree, 4=strongly agree.

IS THERE A USUAL ROUTE?

To understand diversion behavior, it is important to know whether drivers indeed have a regular, or base, route from which they occasionally divert. To answer this question, we analyzed how often respondents used their route, given their trip frequency, as well as the length of time respondents had used their route. Slightly more than 80 percent of the respondents had used the same route for more than 1 year, although about 70 percent had diverted from it occasionally. Drivers were significantly more likely (at the 5 percent level) to use their route for less than a year if they had worked at their current job location or lived at their current home address for less than a year. Furthermore, most drivers took their route regularly, as shown by a high correlation between number of trips and number of times the route was taken (correlation coefficient = 0.88). Respondents over 40 years of age were more likely to have used their route for more than 4 years and, in 3.5 percent of the cases, for more than 20 years. These results imply that most drivers stick to one route as opposed to constantly shopping for new routes. Therefore, it is inferred that there is a usual route that drivers use most frequently and for a longer period of time. At the same time, drivers in this sample did switch routes occasionally.

DELAY EXPERIENCE

More than 62 percent of the drivers knew about an en route delay on their usual route. This figure seemed lower than expected. The concern was that length of the questionnaire (8 pages, 112 questions) might have affected the response to this section; moreover, respondents who skipped this section to save time might introduce a bias because they may have a higher value of time. To address this concern, the following analysis was conducted.

Cross tabulation between the response to whether the respondent knew about a delay and income or education did not show a significant relationship (5 percent level). Further, it was expected (and confirmed) that drivers who experienced longer travel times would be more likely to know about en route delays. Suburban residents were more likely to know about a delay than were Chicago residents, as expected (5

TABLE 6 PERCENTAGE DISTRIBUTION OF RESPONSES TO STATED PREFERENCE QUESTIONS

Conditions on Usual Route	Conditions on Best Alternate Route	Definitely Take "Usual" Route		Neutral		Definitely Take "Alternate" Route	Sample Size
15 minute delay on trip **to work and you must be on time** to work today	No delay from "normal" conditions	25.6	12.7	11.6	14.2	35.9	640
15 minute delay	No delay and **no traffic signals/stop signs** on route	22.4	12.2	14.0	15.9	35.5	630
15 minute delay predicted by your own **observation of heavy congestion**	No information on current conditions	29.7	23.0	19.2	16.6	11.5	640
Jammed (Stop and Go)	No delay from "normal" conditions	12.2	9.1	14.2	21.6	42.9	639
15 minute delay due to **heavy traffic**	No delay from "normal" conditions	19.1	20.0	16.0	18.5	26.4	639
15 minute delay due to **accident**	No delay from "normal" conditions	15.3	15.0	13.3	22.0	34.4	640
15 minute delay **reported on radio**	No information on current conditions	22.6	21.2	25.1	14.8	16.3	637
15 minute delay	No delay from "normal" conditions	21.3	18.2	21.6	16.7	22.2	633
15 minute delay on return trip **from work**	No delay from "normal" conditions	26.7	18.6	15.3	16.7	22.7	633
15 minute delay	No delay but **one traffic signal every one-half mile** of the route	33.9	24.8	19.3	12.8	9.2	632
20 minute delay	No delay from "normal" conditions	15.3	9.5	13.7	22.5	39.0	634
10 minute delay	No delay from "normal" conditions	42.2	21.4	16.7	8.0	11.7	635

percent level). Respondents who made more regular trips and drivers who started work between 8:00 and 8:30 a.m. were more likely to know about a delay. Males were also more likely to know about a delay. Overall, the distribution of negative responses to the delay question seemed reasonable, and there was no obvious discrepancy. Any underreporting to save effort on the survey appears to be uniform across groups.

Length of Delay and Diversion

Several researchers have found that length of delay on the preferred route influences behavior (*3–10*). Increasing delays on the preferred route cause more drivers to divert, and the relationship between length of delay and diversion derived with the stated preference approach resembles an S-shaped curve.

The relationship between length of expected delay and diversion to an alternate route was investigated (see Figure 2). Relatively fewer drivers diverted to alternate routes in response to an expected delay of 10 to 20 min and, as expected, the percentages of drivers diverting increased when the delay increased to 21 to 30 min. However, among drivers who expected the delay to add more than 30 min, the percentage of drivers diverting did not increase. In fact, among the drivers who expected the delay to add 40 min or more to their work trip, only 42 percent diverted. This result is counterintuitive, and possible reasons for it are discussed in the following paragraphs.

The stated preference approach asks people to predict their reactions to delays of specific lengths. Because respondents know the delay length with certainty, it is easy for them to present a rational response (*4,9*). As shown in Figure 3, frequencies of responses to various delay intervals in the stated preference questions (see Table 6) indicate such a rational response. In real-life situations, however, drivers cannot usually know with certainty the length of delay in advance. In retrospect, a driver may feel that large amounts of time could have been saved by diverting; however, initially the delay may not have been threatening enough to divert. As a result, in real life, driver response may not display the same level of rationality. Thus, one reason for a decrease in the percent diverting for large delays may be that delay is perceived incrementally. Furthermore, there were only 24 observations in the more-than-40-min delay category, and this small sample may have contributed to the counterintuitive result.

Other variables, such as trip direction (to or from work) and weather conditions, might have explained why the percent diverting decreased at the upper end of delay distribution. For example, if long delays occur when the weather is particularly bad, no alternate route is likely to be more appealing. The relationship between delay and diversion was investigated while controlling for weather conditions; the results showed that bad weather (rain or snow) did not inhibit drivers from diverting to their alternate routes. In fact, the results suggest that, in bad weather, increasing delays cause the percentage of people diverting to increase.

The relationship between delay and diversion at the upper end of the distribution was unexpected, yet analysis of real-life situations can sometimes give unexpected results. This finding may reveal something about how drivers get information about delays, and it underscores the absence of predictive information about traffic conditions. The contrast between results from this study and those based on stated preferences suggests that more reliable information may lead to increased diversion. For example, the S-shaped response to stated preference questions might be interpreted as an indication of how drivers want to behave, and the irregular response to revealed preference questions might be interpreted as a description of how they must behave given the information they have available.

Saving and Loss in Travel Time

The distribution of saving and loss in travel times due to either diverting or staying on the usual route was investigated. Drivers who diverted were asked to give an estimate of travel time saved or lost by diverting. Drivers who did not divert were asked to give an estimate of the travel time that could have been saved or lost by taking the best alternate route. Of course, these reported time savings or losses are subjective driver estimates, which may be exaggerated consciously or

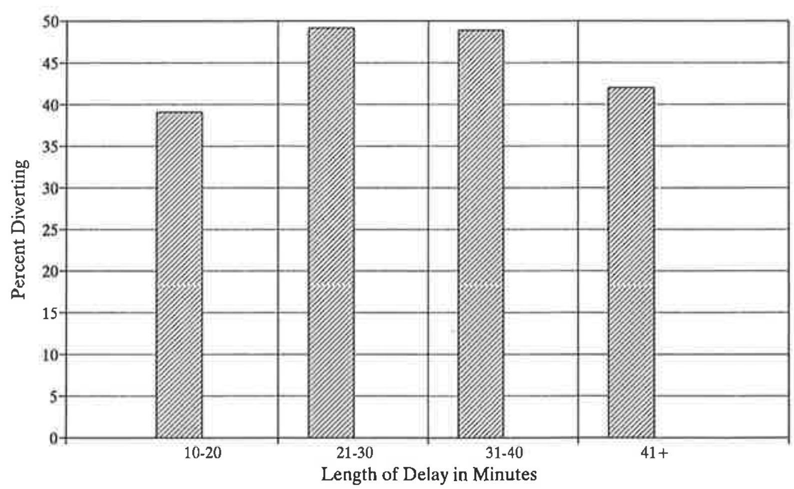

FIGURE 2 Relationship between diversion and length of delay.

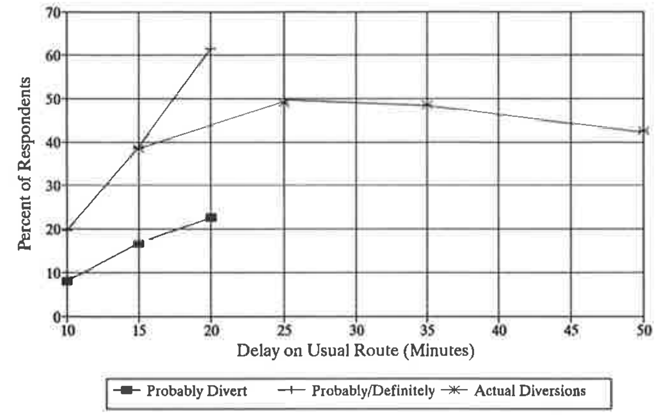

FIGURE 3 Stated intentions and revealed behavior as a function of delay.

subconsciously to rationalize their actions. The magnitudes of travel time saving or loss shown in Figure 4 may represent the travel time thresholds referred to in the conceptualization. The distribution in Figure 4 suggests that 23.1 percent of those who diverted believed that they lost travel time, whereas half of those who continued on their usual route believed that they would have saved time by taking their best alternate. This finding indicates that a substantial number of drivers stay on their usual route, with which they are more familiar, even in the face of a time loss. Furthermore, half of the respondents who believed that they could have saved time by diverting may not have done so because delay may be perceived incrementally. More than 76 percent of those who diverted thought that they gained time, and 26.6 percent estimated the saving to be more than 15 min. The two distributions shown in Figure 4 are bell-shaped. The average saving in travel time for those who diverted was 9.6 min, and the expected loss in travel time for those who did not divert was 4.2 min. Other researchers have found the median delay before diversion to vary between 5 and 27 min (*4,9,10*); therefore, the reported savings in travel times seem reasonable. Again, these savings and losses should be viewed with caution because drivers may exaggerate them to justify their decisions. Nonetheless, statistical analysis suggests that the results are reasonable and consistent with previous studies.

MODELING DRIVER RESPONSE TO DELAY

The effect of several variables on the diversion decision was examined by estimating diversion choice models on the basis of respondents' reported experience of a recent delay. To model choice using utility maximization, knowledge of the decision to be made, the alternatives and their attributes, and the individuals' attributes is needed (*27*). The decision is to divert (to an alternate route) or to stay on the usual route. Although there may be several alternate routes available, these choices were reduced to staying on the usual route and diverting to an alternate. Consideration of more than two alternatives would have added complexity for the respondents and the analysts. The attributes of usual and alternate routes were selected on the basis of research of commuter route choice (*11,28,29*). They included ratings on a five-point Likert scale ranging from "strongly agree" to "strongly disagree" for the following attributes: congestion, scenery, reliability, neighborhood safety, stress experienced while driving, traffic stops, and overall evaluation of the route. The individual attributes include socioeconomic and demographic characteristics, personality (from the self-assessment statements), and attitude toward diversion (from the stated preference questions).

The effects of the following variables were explored:

- Characteristics of the delay experience, such as weather, trip direction, length of delay, and information source on delay;
- Attributes of usual and alternate route;
- Trip characteristics, such as respondents' estimates of travel time on the usual and alternate routes and length of time the usual route had been used; and
- Socioeconomic attributes of the respondents, such as age, gender, income, and location of residence, as well as driver personality factors developed in this study.

Theoretical justification and statistical tests were used to choose among alternative models. Table 7 shows the selected logit model of diversion choice on the basis of these criteria. The signs and magnitudes of the coefficients are as expected. The base for the model was not diverting; therefore, a positive

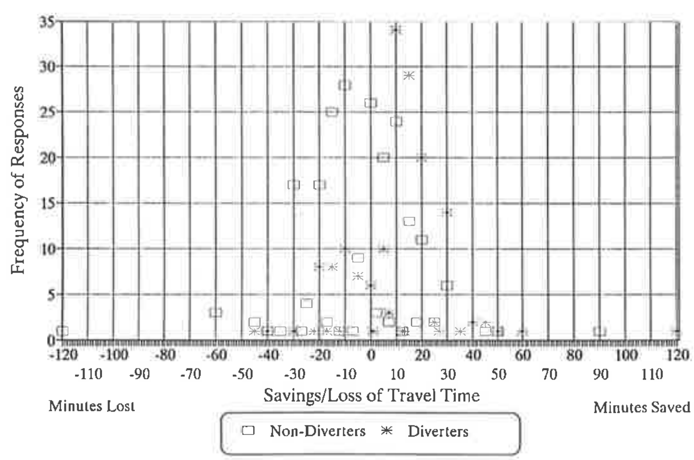

FIGURE 4 Perceived time savings and loss as a function of diversion behavior.

TABLE 7 MODEL OF DIVERSION CHOICE

Variables	Coefficients	(t-Statistics)
Constant	-6.056	(-3.02)
Information source (0=Radio Traffic Report on delay, 1=Observation of delay)	-0.649	(-2.28)
Number of *alternate* routes used (0=0 Routes, 1=1 Route, 2=2 Routes, 3=3 Routes, 4=4+ Routes)	0.303	(2.35)
Alternate route is congested (0=Strongly Disagree, 1=Disagree, 2=Neutral, 3=Agree, 4=Strongly Agree)	-0.243	(-2.00)
Logarithm of length of delay (Minutes)	0.619	(1.53)
Logarithm of Travel Time (Minutes)	0.676	(1.58)
Gender (0=Male, 1=Female)	-0.639	(-2.17)
Stated Preference Index (sum of the scores on stated preference questions normalized by number of statements)	0.682	(4.68)
Personality (sum of the scores on "Adventure and Discovery" normalized by number of statements)	0.412	(2.00)
Residence (1=North suburbs of Chicago, 0=Otherwise)	-0.409	(-1.08)
Residence (1=South suburbs of Chicago, 0=Otherwise)	-1.046	(-2.47)
Summary Statistics		
Initial log-likelihood	-198.24	
Log-likelihood at convergence	-160.19	
Number of observations	286	
Percent correctly predicted	71.33	
Rho-squared	0.1919	
Rho-squared bar	0.1364	

sign indicates increased likelihood of diverting. The sign of the constant is negative, reflecting a preference for not diverting, which is expected because diversion is an unusual occurrence and, even if there is a delay on the usual route, drivers are expected to prefer to stay on it. The null hypothesis that each parameter value is zero can be rejected at the 5 percent significance level except for the delay, travel time, and one of the residential location variables.

Travel time, length of delay, and location of residence have low *t*-statistics; however, these variables are included in the model because longer travel times offer more opportunities for diversion, longer delays on the preferred route prompt drivers to divert, and suburbanites may have a different awareness of urban route alternatives or different levels of comfort with diversion in urban areas. Likelihood ratio tests indicated that none of these variables should be dropped.

It was expected that drivers would be more likely to divert if they observed traffic delays as opposed to receiving delay information through radio traffic reports. Yet the sign of information source is negative, which means that drivers were more likely to take alternate routes if they received delay information through traffic reports. This finding is consistent with those of Heathington et al. (*8*), who found that frequent diverters (due to congestion) were influenced slightly more by traffic reports than by visual observations. Furthermore, Mahmassani et al. (*7*) found that drivers who listened to radio traffic reports were more prone to divert.

Drivers may be more inclined to divert in response to traffic reports because they may have more options at the time they get radio information on incident-induced congestion. By the time drivers observe traffic congestion, they may have committed themselves to a route, or they may not have any real diversion options. The observed delay may be perceived in increments, which may further inhibit a driver from diverting, whereas traffic reports tend to give a more global picture of congestion. Overall, incident-related delay information has potential for modifying driver behavior.

Logarithmic transformation of length of delay and travel time variables was found to be statistically superior to the linear specification. This finding suggests a reduced sensitivity to units of delay and trip time increases; a given percentage increase in the length of delay has the same effect on diversion regardless of the current value of delay. For example, a 5-min increase in a 10-min delay (a 50 percent increase in the length of delay) has the same effect on driver decisions as adding 15 min to a 30-min delay. This finding is reasonable because a driver who anticipates experiencing a half-hour delay may not care that much about an additional 5-min delay, whereas a driver who anticipates a 10-min delay cares more about an additional 5-min delay. The logarithmic transformation seems applicable within reasonable limits of delay (of up to 1 hr). The positive signs indicate that, when delay on the usual route was higher, drivers were more likely to divert; further, if the trip took longer, then drivers were more likely to divert (*5–7*).

A sign for perception of congestion on the alternate route is negative, suggesting that worse congestion on the alternate route inhibits drivers from taking it. This finding underscores the importance of information about congestion on alternate routes. The sign for the number of alternates used is positive, which implies that more knowledge of alternate routes encourages drivers to divert. The number of alternatives used indicates the variety of paths connecting home and work. This variable is an indicator both of cognitive maps of drivers (i.e., driver familiarity with alternate routes) and of the perceived alternatives for diversion. It is inferred that richness of cognitive maps influences diversion behavior.

Among driver characteristics, gender and self-assessment statements about risk behavior are significant. Females were less likely to divert than were males (*6*). The adventure and discovery aspects of driver personality, intended to capture the willingness to take risks and an interest in discovery and exploration, are positively associated with diversion. This factor represents the sum of scores normalized by the number of statements, and the scores vary between 0 and 4. A score of 0 indicates no interest in adventure and discovery, and a 4 indicates great enthusiasm for adventure and discovery.

The stated preference index (SPI) was created by summing and normalizing the responses to the stated preference questions. The scores on this index vary between 0 and 4. Zero indicates that the respondent would definitely take the usual route in all scenarios investigated, and 4 indicates that the respondent would definitely take the alternate route in all scenarios. This index is a measure of a driver's propensity to divert. The SPI has a positive sign, as expected. It is inferred that stated preferences may be good representations of revealed preferences.

SUMMARY AND CONCLUSIONS

Commuter response to delay was investigated in real-life situations to explore the effects of factors such as driver and trip characteristics, route attributes, traffic information, and environmental conditions on driver response to delay. The main advantage of this research design is that it supports investigating driver response to delay and econometric modeling of diversion behavior at the disaggregate level.

En route diversion behavior was found to be influenced by several factors, including source of traffic information, length of delay, gender, travel time, number of alternate routes used, congestion on the alternate route, residential location (city or suburbs), self-evaluation statements about risk behavior (personality), and stated preferences about diverting.

The key finding is that real-time traffic information influences en route diversion behavior. Drivers were more likely to divert when they received delay information through radio reports than when they observed the delay. Thus, real-time traffic information provides a basis for making en route diversion decisions, and drivers actually shift their routes in response to radio traffic information. The use of public and private resources devoted to the collection and dissemination of real-time traffic information can produce benefits for drivers. Other findings are summarized as follows:

- The relationship between expected length of delay and diversion to alternate routes derived from the revealed preference method does not show the clean positive relationship found in stated preference studies, possibly because the true magnitude of a delay is often not obvious to a driver in advance.
- Most drivers who diverted believed that they saved travel time by diverting. The self-reported saving in travel time for drivers who diverted in response to delay averaged about 10 min. Although the self-reported savings may be rationalizations of drivers' diversion decisions, drivers may need some minimum travel time saving, here about 10 min, to justify diverting to alternate routes.
- The number of alternate routes known to drivers, that is, cognitive maps, influence their response to delay.
- A driver's inclination toward adventure and discovery encouraged en route diversion.

If society is to get the most congestion relief from real-time traffic management, transportation planners need to understand how drivers make en route diversion decisions—starting with how drivers use currently available information. This study has shown that it is feasible to conduct empirical studies of such behavior. The results indicate that real-time information is influential in diversion decisions. Moreover, length of delay and perception of traffic congestion on the alternate route influence en route diversion decisions. Therefore, it is recommended that, in the short term, improvements in real-time traffic information focus on developing and disseminating predictions of delay duration due to incidents and the congestion levels on the alternate routes surrounding the incident. This action would require monitoring traffic conditions on the alternate routes along major roadways. Providing clearer information on delays and congestion may contribute favorably to congestion-reducing demand management strategies. In the Chicago area (at least), the provision of real-time traffic information may offer significant untapped potential for better serving suburb-to-CBD commuters. This objective might be achieved by extending the system of detectors further into the suburbs, as well as by monitoring major arterial streets.

ACKNOWLEDGMENTS

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DISCUSSION

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The authors have made a significant contribution to the state of the art in commuter responses to delay. However, I would like to comment on several issues that the authors have raised.

The authors make a distinction between the stated performance approach and the revealed preference approach. The former is defined as what respondents report when asked if they would divert in response to a particular delay. This is an estimate of probable behavior. The latter is based on respondent reports of driver behavior in real-life situations when asked about their actions in previously encountered situations. This is a report of actual behavior in a recalled situation.

Whether or not a driver did or did not divert in a recently recalled situation depends heavily on the information provided the driver by a communication system regarding the extent of delay and the severity of the problem. Real-time changeable message sign (CMS) information from a traffic control center can be very explicit regarding the delay the driver could expect. However, listening to commercial radio reports or simply observing the traffic ahead may leave unspecified exactly the delay that will be encountered. In the first instance, the information may be assumed to be reliable. In the latter instance, it is only a gross estimate.

Research reported by Huchingson and Dudek (*1*) was based on a multistate survey of responses regarding whether or not respondents as drivers would divert to various specified intervals of delay. The objective was to determine those intervals of delay that should be displayed on a CMS. The relationship between delay intervals and reported diversion was found to be S-shaped: few were willing to divert to short delays and virtually everyone was willing to divert to lengthy delays. The curves varied somewhat with the message, i.e., Delay or Time Saved in taking an alternate route.

Two of the more astounding findings of the reviewed study are (a) no more than 50 percent of drivers stated that they would divert regardless of the length of delay; and (b) at durations in excess of 40 min actually fewer drivers would divert than at 31 to 40 min of delay (see Figure 3).

The authors account for this seemingly irrational behavior by stating that in real-life situations drivers cannot know with certainty the length of delay in advance, and, hence, "may not display the same level of rationality to the researcher." They also note that sometimes delay is perceived incrementally and that there were only 24 observations in the delay category of 40 min or more.

The study and the one by Huchingson and Dudek (*1*) may have been based on different assumptions. The S-shaped finding was based on the assumption that reliable information did exist and that given this information drivers were to report how they would react in terms of diversion. In the present study, accurate information was lacking.

Although the findings are not contradictory, there is a risk that the casual reader may conclude that 50 percent of drivers would not divert in the real-world situation and that agencies cannot expect much more voluntary diversion than this. Huchingson and Dudek (*1*) found that in the multistate study only about 4 percent would not divert given that they had reliable information that the delay was 1 hr or more. In the reviewed study, the drivers were not reacting to delay information but rather reporting their diversion behavior in a situation where accurate information was absent.

The data regarding perceived loss or savings in travel time from either diverting or not diverting should be interpreted also in terms of the information available to the drivers in the sample. It was concluded from the study that the average saving in travel time for those who diverted is 9.6 min and that the expected loss in travel time for those who did not divert is 4.2 min. These values were deemed reasonable by the authors because other researchers have also reported that the median delay before diversion varies between 5 and 27 min.

The authors correctly note that the reported estimates may well be exaggerated by drivers to justify or rationalize their decisions. It is true that the drivers had little if any reliable feedback from the information system regarding how much time they actually saved or lost in the situations posed. The specific responses given were based largely on subjective factors unrelated to the actual savings or losses of time.

The authors also conducted a stated preference study with

12 posed situations and reported the percentage of drivers who would take the usual route and diversion route. Nine of the scenarios dealt with 15-min delays. Ten of the best alternate route conditions were given as "no delay"; the other two pose "no information."

The last three scenarios pose 10, 15, and 20 min delay. The percentage data from these delays are plotted in Figure 4 to show how drivers stated behavior differed from their "revealed behavior." This comparison may have been an afterthought for, if the intent was to provide a comparison, the scenarios should have included posed delays of 25, 35, and 50 min. As a control group, it is incomplete.

The upper curve percentages are similar to those found by Huchingson and Dudek (*1*) for 10, 15, and 20 min of delay (18, 34, and 63 percent diversions, respectively).

Huchingson and Dudek (*1*) found 83 percent diversion to 30 min of delay and 95 percent diversion to 60 min. Only 1 percent more (96 percent) would divert to 120 min. Four percent refused to divert. It would seem unreasonable for a large percentage of drivers to sit in stalled traffic for 1 hr given they knew of alternate routes with traffic moving.

The authors pose an interesting theory regarding how anticipated delay relates to knowledge of additional delay. This "proportional delay theory" is illustrated by the following cited example. "For example, a 5 minute increase in a 10 minute delay (a 50% increase in length of delay) has the same effect on a driver's diversion decision as adding 15 minutes to a 30 minute delay." In other words, the longer one expects to be delayed in traffic, the greater the percent increment in delay required before the driver will be concerned. The authors state that this effect applies up to 1 hr of delay. Thus, a logarithmic rather than a linear transform was used in the model.

Although this theory has some plausibility (generalizing from Weber's Law in psychophysics), no data were cited to merit the adoption of the model other than "the log transform gave slightly better statistical results." This theory should be tested by a parametric study presenting various levels of delay and noting if there was reduced time sensitivity as units of delay and trip length increase.

There are interesting findings from the study related to driver characteristics (gender and personality) and the length of the commute. However, the traffic engineer attempting to apply the findings to real-world problems must be fully aware that the drivers in the study had limited information on the actual delay times on the usual and alternate routes. Further, the study findings may be situationally specific. Characteristics of the alternate routes in the Chicago area in terms of their desirability for diversion may be quite different from those in another major metropolitan freeway system. There may also be seasonal variations (e.g., heavy snowfall affecting all facilities). Caution must be applied when attempting to generalize from the data to other cities. The findings should be accepted recognizing that the drivers had precious little real-time information on time saved or lost or feedback in the time domain. The numbers reported in the survey should be viewed in that light.

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