DIRECT
Operational Field Test Evaluation Natural Use Study

Part 2: Driver Satisfaction in DIRECT Controlling for Reliability

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ABSTRACT

One of the most difficult aspects of evaluating an operational field test is obtaining consumer response to products or services that are not market ready or even completely functional. The DIRECT (Driver Information Radio using Experimental Communication Technologies) operational field test compared consumer response to four new low-cost advanced traveler information systems (ATIS):

- Automatic Highway Advisory Radio (AHAR),
- Low Power Highway Advisory Radio (LPHAR),
- Cellular telephone call-in, and
- Radio Data System (RDS/SCA).

These systems were compared to each other and to a control group of drivers using standard radios and receiving commercial traffic reports. These systems were selected because at little cost they could alert drivers to traffic conditions:

- on-demand (versus periodic access to traffic information)
- specific to the routes (versus area-wide information), and
- automatically interrupting if a new incident was identified.

Nevertheless, because all of the systems evaluated in this study were limited-deployment pre-market implementations the subjects experienced a variety of reliability problems. The problems ranged from receiving incomplete reports of traffic problems to frequent radio interruptions with mundane traffic information.

The evaluation presented this report addresses the drivers' level of satisfaction controlling for these reliability issues. The evaluation was conducted by setting the system reliability measures, based on driver survey responses, equal across each of the test systems including the control group. The analysis used a combination of principal component analysis (PCA) and regression analysis, reducing the evaluation to four intuitively appealing factors that explained most of the differences among the systems. The principal components scores from the PCA were used in the regression analysis to estimate the driver's satisfaction.

The four principal components accounted for 73 percent of the total variance. This means that four factors explain about 73 percent of the variation in the 15 original variables. The first component is mostly related with system reliability measures like providing reliable information, working reliably, accuracy of the information provided, relevance of the information, timeliness of the information, and report frequency. The second component can be referred to as information targeting and included expected length of delay, reason for delay, relevance to the route, and providing the information on demand. The third component is related to human factors considerations and includes ease of use, convenience, and getting the driver's attention. The last component is related to driver distraction.

The regression analysis suggests that the four principal components have positive influence in determining the driver's satisfaction explaining 53 percent to 66 percent of the variation, The comparison between "with" and "without" controlling the system reliability for the nine outcome variables revealed some interesting findings. First, without controlling the reliability the

performance of the two systems, RDS/SCA and the control group (Radio) were about the same. However, when system reliability was controlled, as described above, RDS/SCA was elevated to the most preferred system. Second, the paired samples test analysis revealed that there are significant mean differences between with and without controlling the reliability for the outcome variables of the four experimental traffic information systems including the control group. In addition, the four study groups gained higher improvement than the control group for the outcome indicators when we were able to control the reliability.

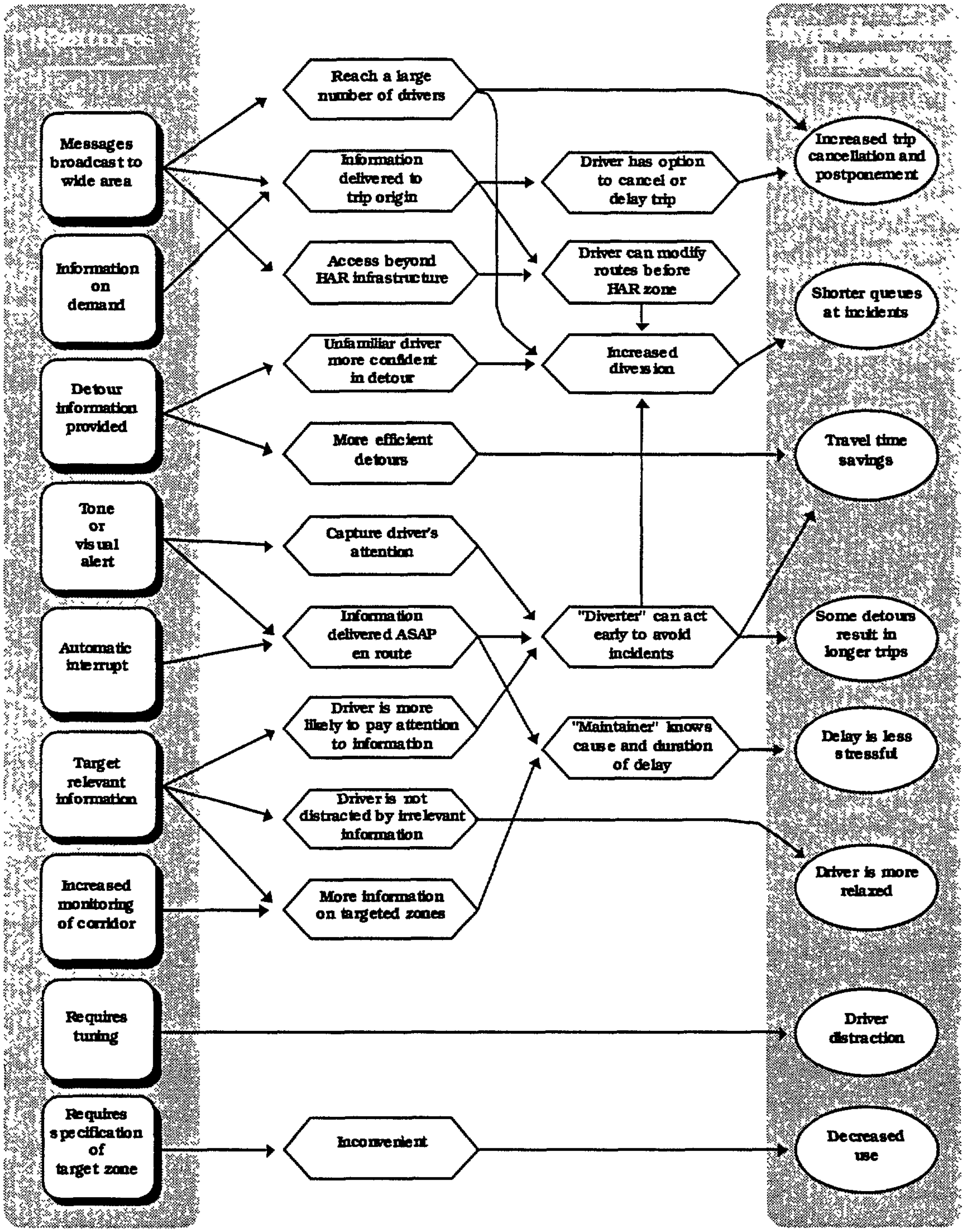
DRIVER SATISFACTION IN DIRECT: CONTROLLING FOR RELIABILITY

The traveler's need for traffic information has not gone unnoticed. Radio stations that target the commuter have long recognized this need, and they meet this need by providing periodic reports on traffic conditions, identifying blockages and suggesting possible detours. Sometimes radio alerts can help the listener avoid delay due to an incident. If the are already stopped the jam, a traffic report can at least describe the situation to perhaps reduce driver frustration due to uncertainty. However, the effectiveness of standard radio broadcasts is limited because (1) broadcasts are not geographically targeted to motorists in the problem area, requiring all motorists to listen attentively to all the periodic messages, and (2) reports are not continuously available, possibly resulting in a critical lag between the time the motorist needs to know and the time the report is actually transmitted. As a result, even the attentive motorist probably does not have access to all the relevant traffic information that ***could*** be available.

Recognizing these limitations product developers are looking into new and innovative communication approaches to move beyond the commercial radio traffic reports. Some of the new approaches, such as those that include advanced displays, vehicle navigation and route guidance, are still quite expensive and generally inaccessible to the majority of the driving public. However, other innovative approaches that use existing radio equipment and infrastructure, or less expensive designs and components, are more likely to be accepted and used by a greater proportion of the driving public. Thus, these approaches are likely to have a larger and more immediate impact on motorist behavior and current traffic management practices. These low-cost information systems are the focus of the DIRECT operational field test and evaluation.

The following diagram shows the connections between some of the features of these low-cost methods and their hypothesized impacts, including drawbacks and benefits. The features affect driver behavior, resulting in the hypothesized impacts. Neither the list of features nor the hypothesized impacts list is exhaustive; however, the diagram demonstrates the relationship between a technical capability and its potential for affecting deployment (see Figure 1).

Figure 1. Connection between the system features and the hypothesized impacts



1.1 Field Test

The DIRECT OFT. was conducted along I-75 (also known as the Chrysler Freeway including the area just north of I-696 south to downtown Detroit. Subjects for the controlled base fleet study were recruited from those drivers who commute daily to downtown via I-75. The goal of the DIRECT project was to evaluate the user benefits, institutional issues and technical issues of en-route driver advisory and traveler information services in an operational setting. Emphasis was placed on testing and evaluating the voice-based communications systems that offered:

- basic services at a minimal incremental cost to the traveler; and a
- high potential for operational deployment.

The DIRECT operational test and evaluation is unique because it is designed to test and evaluate several competing approaches for providing localized traffic information to drivers at a modest cost. Therefore, the project emphasizes low cost yet innovative ways to achieve the established goal. Drivers participating in this project received information on current incidents ahead on their chosen routes. This information was sufficiently timely to provide drivers with the opportunity to divert from their original path. The methods tested in the project, discussed later in this section, seek to improve incrementally the traditional methods of receiving traffic information; messages were more localized, faster, more accurate, route-specific, or available on demand. Because the test is a comparison of four different systems, the features among them differ.

Low Power Highway Advisory Radio (LPHAR)

The DIRECT project is deploying two forms of HAR for testing and evaluation: low power highway advisory radio (LPHAR) and automatic highway advisory radio (AHAR). With LPHAR, the roadside transmitter uses an HAR frequency along with analog amplitude modulation to deliver (one-way) exception traffic information on “incidents ahead on this roadway” or incidents on “the roadway that intersects at this exit.” LPHAR is distinguishable from conventional HAR because it uses relatively low power (3 versus 10 watts) to illuminate a roadside zone about 1 .0 to 1.5 miles in length. While LPHAR offers the same basic communication features as HAR, it permits both a more definite area where the signal strength is good, and allows the installation of another transmitter as little as a mile away without interference. Like HAR, LPHAR requires a road sign announcing the availability of the information. In this application flashing lights informed project participants that there is a traffic situation ahead and they should tune to the radio for information. The lights flashed when no exception congestion existed. However, when the participants tuned to the frequency when no light is flashing, a standard “normal conditions” message was be heard.

An attractive feature of LPHAR is that it operates on a standard radio frequency and does not require anything more than a standard automobile radio. Additionally, the frequencies for transmission have been allocated (on a secondary basis) across the nation. Some operating concerns with LPHAR are: (1) it requires either manual tuning or button pre-tuning and a “button-push” when passing a flashing sign; (2) providing a good signal over a specified “message zone” has not yet been demonstrated on a roadway; (3) an AM signal can experience unavoidable noise from nearby and distant thunderstorms; and (4) the infrastructure cost may be high.

Automatic Highway Advisory Radio (AHAR)

During the 1980s, the FHWA embarked on an effort to explore the delivery of relevant traffic information to a driver automatically (if the driver a priori chooses it). This requires a method of opening up the receiver to the traffic message, which must be directionally sensitive. While this effort used an “enable” transmitter placed ahead of the message transmitter, current conditions suggest that the enable function can be performed by the same basic technology as is currently used for tolling (Automatic Vehicle Identification-AVI). The AHAR system functions in the following way-a “reader” delivers a digital control signal to the passing vehicle. The control signal can also be accompanied by data which could relay the particular local vacant (broadcast FM) frequency on which the message itself can be heard. This would automatically tune the receiver to that frequency. If a non-broadcast frequency were used, then a new FM receiver would have to be introduced with this technique. For the driver, the effect is an automatic interrupt of exception traffic messages through the radio. No tuning is required. This project used a 220 MHz frequency, specially acquired by the FHWA from the FCC.

Some operating concerns with AHAR are: (1) the infrastructure cost may be high; (2) the in-vehicle cost may be high if a new FM receiver is needed; (3) control circuitry is needed in the vehicle; and (4) an existing toll-tag could already be the in-vehicle receiver.

Cellular Telephone Call-in System

This system uses the existing cellular infrastructure and the installed telephone base to provide drivers who use the system with current traffic information. The idea was to have the motorist call the traffic information service and, through a series of queries, obtain traffic information that affects his or her travel plans. Basically, by calling a single number, a cellular subscriber could access a dynamic incident database through which route specific information could be obtained by dialing certain digits. The benefits of this system are that drivers can access the system at any point in their trip, and the information is targeted to the driver and relevant to the planned trip. As a method, cellular call-in allows drivers to receive information before they begin their trip, so they may alter their route at the start of their trip, rather than in the middle. A potential drawback is that message delivery is dependent on driver initiative; if the driver does not call, no information is received.

Radio Broadcast Data System (RBDS)

RBDS is similar to the Radio Data System (RDS) originated in Europe and is designed to improve upon standard FM radio broadcasts by transmitting data on the FM “sideband’‘-the supplemental FM frequency allocated to a radio station. The system uses a sub-carrier at 57 KHz of any existing FM station to provide a digital signal, and hence enjoys a low infrastructure cost. The station then uses the sideband to transmit data to specially equipped RBDS radio receivers, providing a one-way area-based digital communication link, of limited capacity, for exception traffic messages. The data may be encoded before transmission and decoded on-board the vehicle. The messages may also contain a vehicle location field to enable “intelligent” receivers to screen for relevant messages. The objective is to send concise data messages concerning current traffic problems in parallel with the standard entertainment broadcast. When filtered and decoded the messages can be complex and tailored to the driver and the trip.

The digital RBDS sub-carrier can only control (and possibly filter) the introduction of messages into the vehicle; some means must be provided to deliver the analog messages themselves. The DIRECT project used another sub-carrier (at 76 KHz) from the same FM station to carry the analog voice traffic messages. The standard RBDS radio was outfitted with an additional sub-carrier decoder (already available on a chip), with access to this signal interfaced with the control information on the RBDS digital sub-carrier. This use of existing FM station capability (by using the sub-carriers) required cooperation with FM radio stations.

The use of FM sub-carriers has two advantages: (1) permitting examination of exception incidents before the trip, for route planning purposes, and (2) an automatic-interrupt alert service for new incidents en-route. The pre-trip information is available on-demand anywhere in the FM station coverage area. If filtering methods can be developed, only messages specific to the route of interest will be heard or will interrupt the driver. Some operating concerns with RBDS are: (1) the low capacity of the RBDS digital sub-carrier (100 to 200 bps available), (2) the potential conflict between the commercial announcement strategy of a station and a no-delay goal of announcing new incidents; and (3) the impact of any non-100% reliability (error-rate) on introducing delay.

The Table 1 summarizes how the information delivery methods being tested in the DIRECT project compare across system six features.

Table 1. Comparison of DIRECT System Features

Features	AM-FM	AHAR	LPHAR	Phone	RDS/SCA
Manual Action by Driver	—		--	—	
Automatic Driver Alert		—			—
Pre-Trip Access	—			—	—
En-Route Access	—	—	—	—	—
Route-Specific Messages		—	—	—	—
Standard Radio Sufficient	—		—	NA	

The systems evaluated in DIRECT are low-cost and technically simple compared to route guidance and other traveler information systems. But it is important to perform a comprehensive comparative evaluation of these “first wave” systems to assess their relative merits and to establish a baseline for comparison with more advanced ATIS.

Most of the planned operational field tests of ATIS address a single information delivery method. Under these circumstances comparisons among delivery methods are confounded by inconsistencies in the deployment environments among the various test sites. DIRECT provided an unique opportunity to compare alternative systems for delivering motorist information because the systems were implemented and tested along the same corridor, providing an essential control element missing in other evaluations.

The systems to be compared was implemented on the same corridor to control for variation in traffic, weather, and geographic conditions. The comparison focuses on user attitudes and preferences, and on projected system level effects. In addressing these questions, any statement of comparative benefit should be made with reference to baseline measurements from a conventional AM-FM broadcast reporting system. The test area also has some variable message signs that were considered part of the baseline.

1.2 Evaluation Objectives

The overriding purpose of DIRECT is to compare the alternative modes of en-route travel information delivery in terms of benefits and costs. The single-site test design provides a unique opportunity to accomplish this. The results from the evaluation should be useful in several respects. First, service providers will benefit from our evaluation advantages and disadvantages of each delivery system.

A natural-use method was used to assess both cognitive and behavioral responses of drivers in the study. The idea underlying a natural-use study is that consumer use and attitudes vis-a-vis a new and innovative product or service evolve as the consumer gains experience with the product or service. Although first impressions are important from marketing and use standpoints, the consumer only came to appreciate the advantages and disadvantages of a product after using the product over time and under natural-use conditions.

For example, it may be difficult to tell how often a consumer used a cellular call-in traffic information service. At first glance it may seem like a useful service. But over time a driver may forget about the service until it is too late to take action. Then the driver may be perturbed that he or she did not have an adequate chance to act. However, the driver may decide that at least knowing the cause and duration of the congestion is better than having no information. Because of these possibilities, evaluations of stated and observed behavior made prior to providing the consumer with sufficient product experience may inadequately describe driver experience over time. Therefore, the evaluator must allow a representative sample of the target market population to use the product or service over a prolonged period of time, under natural conditions. Through this experience, participants become familiar with a product’s advantages and disadvantages, before their responses are evaluated.

To keep the project duration to a minimum and to avoid learning effects, each participant used only one information delivery method. The exception to this rule is the baseline, consisting of commercial radio traffic reports and changeable message signs along the expressway, which was available to all subjects. This constraint arises because effects due to individual information delivery systems are separable only if the systems are truly independent. If a subject forms an opinion or acts on the basis of accessing information through multiple avenues, it is impossible to determine which avenue produced the cognitive or behavioral change.

Table 2 shows the post-test-only-control-group quasi-experimental design planned for the base-fleet study (Campbell and Stanley, 1963). The foundation of this design is between-subject analyses and the inclusion of a control group against which results from each of the technology conditions can be compared. The control group is included in lieu of collecting before and after data. As the table shows, it was planned that the base-fleet consisted of six two-month periods of 25 subjects each, for a total of 150 subjects over 15 months (15 months instead of 12 to provide two-weeks between groups for vehicle maintenance and preparation for hand-off to the next group). The 25 subjects in each period were divided into five test conditions of 5 subjects each. Subjects drove project-supplied vehicles along the test corridor, I-75, to and from downtown Detroit on their daily commute. The vehicles had devices to track the actions of subjects.

Table 2. Design for the Base-Fleet Study

			Traffic Information System				
Test Period	Duration	Task	Control	LPHAR	AHAR	RBDS	Cellular *
1	2 weeks 2 months	Distribution of vehicles and driver orientation Subject Natural Use (record driving times/routes; survey after 1 week & 2 months)	nl=5	n2=5	n3=5	n4=5	n5a=2 exp. n5b=3 no exp.
2-5	...	...	...	...	...	...	...
	...	...	...	...	...	...	...
6	2 weeks 2 months	Distribution of vehicles and driver orientation Subject Natural Use (record driving times/routes; survey after 1 week & 2 months)	nl=5	n2=5	n3=5	n4=5	n5a=2 exp. n5b=3 no exp.
Total Duration			Total Number of Subjects in Study: N=150				
15 months			N1=30	N2=30	N3=30	N4=30	N5a=12 exp.
							N5b=l8 no exp.

Two "Cellular" groups are described: "experienced" (exp.) and "no experience" (no exp.). These titles describe two sub-conditions within the "Cellular" test. Specifically, these describe persons who have experience using cellular phones in vehicles and those without such experience. The purpose is to experimentally control for suspected differences in attitudes and behaviors associated with users of the cellular traffic information system between subjects accustomed to using cellular phones versus those to whom cellular phones are new and novel.

Table 2 shows five subjects per period belong to a control group. For this group, vehicles were equipped with only the behavior tracking system; no information delivery system other than existing sources were made available to control-group subjects. Each of the five subjects in the second through fourth (technology) groups drove a vehicle equipped with a tracking system and one of four information delivery methods being tested (LPHAR, AHAR, RBDS/SCA, and Cellular Call In).

The appropriate number of individuals from the recruited subjects were randomly assigned to one of the eight project periods (two-months each). Furthermore, within each of the two-month periods, subjects were randomly assigned to either the control group or to one of the four technology conditions (one of the four traffic information delivery systems). Subjects were not paid for participation because the project-supplied vehicles were sufficient incentive for recruitment and sufficient reward for subject retention. Subjects were responsible for fueling the vehicles, but routine maintenance and insurance was provided by MDOT.

Data collection for the attitudinal, behavioral, and outcome evaluation questions follow the schedule shown in the task column of Table 2. Data was collected through: (1) interviews and surveys, (2) behavior tracking, and (3) a database of incidents, and the messages transmitted to subjects. Survey and interview activities primarily address the cognition questions, but illuminate behavioral issues as well. Behavior tracking primarily addresses the behavior and outcome questions, and the incident message database supports behavior and cognition analyses.

1.3 Survey and Interview Data

Approximately one week into their experience, subjects were contacted via phone to elicit their response to a short series of carefully targeted questions. This contact also represents an opportunity for subjects to describe their first impressions. Any problems encountered can also be reported, and hopefully solved, at this time. A detailed questionnaire on the experience was administered at the termination of each subject’s two-month participation period. In addition to the survey, each subject was thoroughly debriefed in an interview by trained evaluation personnel. Debriefing interviews followed a semi-structured interview process, including note-taking by the interviewer, and possible audio tape-recording. The debriefing occurred directly after participants respond to the detailed questionnaire. Thus, entries in the survey and interview data file take the form of answers to both closed and open questions.

The cognitive measures of interest include the following driver experiences:

- Perceived accuracy, timeliness, and relevance of the localized traffic information provided.
- Confidence in the traffic information provided.
- Confidence in the information system tested.
- Satisfaction with the information system tested.
- Perceived improvement of commute attributed to availability of information.
- Reported attention to the messages available.

- Perceived degree of distraction due to using the information system tested.
- Willingness to pay for information/delivery system such as that tested.
- Stated reasons for diverting/not diverting when an incident message is received.

These measures of effectiveness established the subject preferences and attitudes regarding the systems as deployed in the field.

CONTROLLING RELIABILITY

The purpose of DIRECT was to compare alternative communications technologies along with the services enabled by the technologies. While the viable options for communicating traffic information to the driver have matured over the last few years, the concept for a useful and marketable traffic information service is still not resolved. While there has been a lot of research on driver attention and the computation of traveler choice alternatives, there has been little research on driver wants and needs, or on how the services should be provided to support selection among travel alternatives (FHWA, 1997).

The DIRECT service evaluation was essentially a specialized form of new product testing with a focus on the driver or market user. The purpose of product use testing is to see whether the service meets design specifications, to obtain ideas for design improvement, to learn modes of use, to verify potential service claims, and to assess the consumers' willingness to purchase the service. Whereas the standard strategy for new product testing is to experiment with and improve the design of a single product, the DIRECT evaluation compared a set of alternatives including a control group receiving standard radio broadcasts. The intent was to gain insight about the provision of traffic information services and potentially improve on periodic traffic reports offered by commercial radio stations. These paired comparisons of alternative traffic information services was important to the public because often traffic information services are based in public agency data provided for the purpose of regulating traffic, especially under incident conditions. If the service does not help with traffic and safety, then it is of little public interest. The results should also be of interest to the private information service providers, the ATIS receiver companies, communications companies, and the automotive companies. A controlled evaluation, as opposed to a "launch and track" approach, was deemed appropriate because of the high stakes of associated with public and private involvement in ATIS, and because of the high level of environmental, market, and organizational uncertainty associated with deploying a traffic information system (Banks, 1965).

Furthermore, an important purpose of DIRECT was to help improve the service by providing consumer guidance for eliminating failures and improving winners (Urban, Hauser, Dholakia, 1987). While a "blind test" approach was not feasible given prolonged exposure requirements and learning effects, a statistically controlled comparison between groups was possible in DIRECT. Preferences were obtained through surveys where consumer preferences were recorded in the range of "strongly agree" to "strongly disagree" on five point scales. The consumer test results provide insight for reducing risk and increasing benefits to ensure that the traffic information services were of value to the test subjects and potentially competitive in the automotive options market.

One of the most difficult aspects of evaluating an operational field test is obtaining consumer response to products or services that are not market ready or even completely functional. The DIRECT operational field test compared consumer response to four different types of advanced traveler information systems (ATIS) to evaluate which aspects of ATIS products and services drivers preferred. The subjects were asked to drive vehicles with the new driver information systems and to report their perceptions and preferences about their experience. Unfortunately, because all of the systems were limited-deployment pre-market implementations the subjects experienced various reliability problems, ranging from incomplete reports on the incidents to frequent interruptions of their radio with mundane information.

Reliability issues included light malfunctions in the LPHAR, transmission failures in AHAR, and the inaccessibility of the cellular call-in service. These systems-specific reliability issues posed a special problem for the evaluation because of how important reliability is to drivers using a traffic information. Another aspect of the problem was that the severity and frequency of these difficulties in delivering the information were not representative of a fully deployed commercial service. So system reliability needed to be controlled in order to get a grounded assessment of the relative value the drivers had of each of these systems.

Nevertheless, the evaluators collected large amounts of attitudinal, preference, and performance data on these systems with the intent of gaining some insight on the features and systems that the consumer would like the best. Fortunately, the evaluation plan anticipated the possible difficulties with systems reliability and specified a questionnaire that would allow control for the possible influence on the subjects response. This report presents the background for the field experimentation and focuses on the results where driver attitude toward system reliability was statistically controlled.

2.1 Evaluation of DIRECT Traffic Information System

In this section we will present an evaluation model for DIRECT traffic information systems. As noted above, the new systems including AHAR, LPHAR, cellular telephone call-in (PHONE), and RDS/SCA are designed without standard operations and maintenance support. As results, the systems did not operate at high levels of reliability. Unfortunately, the evidence shows that low levels of operational reliability affected the subject appreciation of the system features and capabilities. The evaluation model is designed to measure the driver's satisfaction that allowed us to set reliability equal across the all four systems being investigated and the control group.

The model was developed as a combination of principal component analysis (PCA) and regression analysis. The PCA is mainly meant to reduce the number of system attributes to a few components such that each component form a new explanatory variable and the number retained component explains the maximum amount of variance in the data. Then, the principal components scores resulting from the PCA will be used as explanatory variables for regression analysis in estimating the driver's satisfaction. The two most widely used statistical packages, the Statistical Package for the Social Science (SPSS) and the Statistical Analysis System (SAS), were used in performing the PCA and regression analysis.

In order to develop the evaluation model, we followed two main steps. The first step is to perform PCA involving the 15 system attributes. It also includes generating component scores for individual observation. The second step is to perform linear regression analysis involving the retained components as explanatory variables and the system benefits such as driver's satisfaction variables as the dependent variables. Each dependent variable will be regressed on the extracted components. In the analysis, the driver's satisfaction indicators will be estimated with and without controlling the reliability aspect of the all systems being investigated and the control group.

2.2 Principal Component Analysis

The formal objective of principal component analysis involving the 15 system attributes algebraically can be stated as follows.

$$F1 = w_{11}x_1 + w_{12}x_2 + w_{13}x_3 + \ldots\ldots + w_{115}x_{15} \quad \ldots\ldots (1)$$

$$F_2 = W_{21}X_1 + W_{22}X_2 + W_{23}X_3 + \ldots\ldots + W_{215}X_{15}$$

$$F_3 = W_{31}X_1 + W_{32}X_2 + W_{33}X_3 + \ldots\ldots + W_{315}X_{15}$$

$$F_p = W_{p1}X_1 + W_{p2}X_2 + W_{p3}X_3 + \ldots\ldots + W_{p15}X_{15}$$

Where F1, F2 . . .Fp are the p principal components and W_{p1} is the weight of the first variable for the pth principal component. The first principal component (F1) accounts for the maximum proportion of total variance explained in the data, the second principal component (F2) accounts for the maximum variance that has not been accounted for the first principal component, the third principal component (F3) accounts for the maximum variance that has not been accounted for the first two principal components, and so on. X1, X2, ... and X15 denote system attributes.

The names, descriptions, means, and standard deviations for the 15 variables are presented in Table 3. These variables can be interpreted as direct measures of the driver's perception on the Direct traffic information system features. The all system variables have the same scale in which 1 represents strongly disagree and 5 represents strongly agree. The sample means for these variables range from 1.927 for Suggesting Alternate Routes (X15) to 4.229 for Easy to Use (X8) with sample size between 95 and 97 observations. The standard deviations, as a measure of variability of the data, extend from the lowest (1.078) for Suggesting Alternate Routes (X15) to the largest (1.650) for Reporting Frequently Enough (X7). Another indicator that can be used to measure relative dispersion in the data is coefficient of variation (Salvator, 1982). This coefficient is a useful measure for comparing the relative dispersion of two or more distributions. The coefficients of variation, as presented in Table 3, vary from the smallest (0.253) for Easy to Use (X8) and Convenient to Use (X9) to the largest (0.657) for Providing Info on Demand (X14), implying that data of the latter is much more dispersed than that of the former. Overall, the descriptive statistics do not indicate over-dispersion in the raw data.

Table 3. Sample Descriptive Statistics

System Attribute	Mean	Std	Coefficient of variation (V) *
Working reliably (Xl)	2.351	1.385	0.589
Including info need to know (X2)	2.333	1.254	0.537
Specific to con-mute (X3)	3.354	1.465	0.437
Providing reliable info (X4)	2.663	1.411	0.530
Providing accurate info (X5)	2.750	1.407	0.512
Reporting incidents soon (X6)	2.684	1.315	0.490
Reporting frequently enough (X7)	3.052	1.650	0.541
Easy to use (X8)	4.229	1.071	0.253
Convenient to use (X9)	4.198	1.062	0.253
Catching my attention (X10)	3.865	1.193	0.309
Distraction (values in reverse order) (X11)	3.250	1.338	0.412
Giving reasons for delays (X12)	3.484	1.304	0.374
Giving expected length of delays (X13)	3.115	1.321	0.424
Providing info on demand (X14)	2.240	1.471	0.657
Suggesting alternate routes (X15)	1.927	1.078	0.560

Note:

1 = strongly disagree, 2 = somewhat disagree, 3 = neither, 4 = somewhat agree, and 5 = strongly agree

**) Coefficient of variation = (std/mean).*

Table 4. Correlation matrix

		Working reliably	Including info need to know	Specific to commute	Providing reliable info	Providing accurate info	Reporting incidents soon	Reporting frequently enough	Easy to use	Convenient to use	Catching my attention	Distraction (values in reverse orde	Giving reasons for delays	Giving expected length of delays	Providing info on demand	Suggesting alternate routes
		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
Working reliably	X_1	1.000	0.687	0.159	0.692	0.669	0.575	0.401	0.262	0.251	0.272	0.348	0.433	0.236	0.251	0.363
Including info need to know	X_2	0.687	1.000	0.416	0.739	0.710	0.559	0.409	0.264	0.290	0.249	0.320	0.515	0.390	0.356	0.470
Specific to commute	X_3	0.159	0.416	1.000	0.462	0.447	0.294	0.354	0.102	0.130	0.148	0.062	0.477	0.506	0.351	0.256
Providing reliable info	X_4	0.692	0.739	0.462	1.000	0.911	0.736	0.504	0.253	0.255	0.299	0.319	0.493	0.349	0.396	0.394
Providing accurate info	X_5	0.669	0.710	0.447	0.911	1.000	0.719	0.486	0.255	0.259	0.262	0.347	0.563	0.418	0.441	0.446
Reporting incidents soon	X_6	0.575	0.559	0.294	0.736	0.719	1.000	0.399	0.335	0.285	0.326	0.343	0.514	0.445	0.312	0.308
Reporting frequently enough	X_7	0.401	0.409	0.354	0.504	0.486	0.399	1.000	0.458	0.378	0.495	-0.068	0.455	0.340	0.255	0.186
Easy to use	X_8	0.262	0.264	0.102	0.253	0.255	0.335	0.458	1.000	0.857	0.618	0.055	0.438	0.316	0.132	0.215
Convenient to use	X_9	0.251	0.290	0.130	0.255	0.259	0.285	0.378	0.857	1.000	0.586	0.106	0.390	0.224	0.084	0.270
Catching my attention	X_{10}	0.272	0.249	0.148	0.299	0.262	0.326	0.495	0.618	0.586	1.000	0.041	0.347	0.237	0.001	0.172
Distraction (values in reverse order)	X_{11}	0.348	0.320	0.062	0.319	0.347	0.343	-0.068	0.055	0.106	0.041	1.000	0.203	0.043	0.156	0.356
Giving reasons for delays	X_{12}	0.433	0.515	0.477	0.493	0.563	0.514	0.455	0.438	0.390	0.347	0.203	1.000	0.779	0.333	0.483
Giving expected length of delays	X_{13}	0.236	0.390	0.506	0.349	0.418	0.445	0.340	0.316	0.224	0.237	0.043	0.779	1.000	0.365	0.316
Providing info on demand	X_{14}	0.251	0.356	0.351	0.396	0.441	0.312	0.255	0.132	0.084	0.001	0.156	0.333	0.365	1.000	0.343
Suggesting alternate routes	X_{15}	0.363	0.470	0.256	0.394	0.446	0.308	0.186	0.215	0.270	0.172	0.356	0.483	0.316	0.343	1.000

Table 4 contains correlation matrix of the 15 system attributes. It reveals that some variables are inter-correlated with each other with correlation coefficient of greater than 0.5. For example, Working Reliably (X1) is highly correlated with Including Info Need to Know (X2) (0.687), Providing Reliable Info (X4) (0.692), Providing Accurate Info (X5) (0.669), and Reporting Incidents Soon (X6) (0.575). Similarly, Providing Reliable Info (X4) is largely correlated with Including Info Need to Know (X2) (0.739), Providing Accurate Info (X5) (0.91 l), Reporting Incidents Soon (X6) (0.736), and Reporting Frequently Enough (X7) (0.504). This multicollinearity is certain to cause problem if we attempt to estimate the regression with straightforward least-squares. Under the circumstances, to isolate selected variables or single variable as the determinants--such as Working Reliably (Xi), Providing Reliable Info (X4), Specific to Commute (X3), Easy to Use (X8), and Suggesting Alternate Routes (X15) -- and use them in the regression results the risk of omitting relevant variables and oversimplifying the explanation.

In this section we will retain all the 15 original variables and reduce their dimensionality and eliminate the interaction by using principal component analysis.

Table 5. Total Variance Explained

	Initial Eigenvalues		
Component	Total	% of Variance	Cumulative
Component 1	6.450	42.998	42.998
Component 2	2.017	13.448	56.446
Component 3	1.413	9.422	65.869
Component 4	1.061	7.076	72.944
Component 5	0.756	5.043	77.987
Component 6	0.644	4.292	82.279
Component 7	0.601	4.006	86.286
Component 8	0.484	3.226	89.512
Component 9	0.398	2.656	92.168
Component 10	0.369	2.461	94.629
Component 11	0.246	1.643	96.272
Component 12	0.218	1.455	97.727
Component 13	0.143	0.956	98.683
Component 14	0.122	0.813	99.495
Component 15	0.076	0.505	100

Extraction Method: Principal Component Analysis.

Table 5 presents the statistics for each component. The percentage of the total variance attributable to each component is listed in the column labeled '% of variance’. For example, the total variance explained by linear combination formed by component 1 and component 2 is 42.9 percent and 13.4 percent, respectively. The last column, the cumulative percentage, labeled ‘Cumulative %’ indicates the percentage of variance attributable to that component and those that precede in the table. As can be seen in the table, the first four principal components have eigenvalues greater than one. These four components account for about 73 percent of the variance. The eigenvalue represents the amount of variance accounted for by a principal component. Detail discussion on how to calculate the eigenvalues is available in Johnson and Wichem (1998).

There are several criteria that we can use in determining number of principal components to extract. The extraction rules include the eigenvalue-greater than one rule, scree plot rule, and percentage of variance rule. A combination of the eigenvalue-greater-than-one and percentage of variance criteria rules is selected as the method of extraction in determining the number of principal components that should be retained. The main reason is to ensure practical significance for the retained factors by ensuring that they account for at least a specified amount of variance. Hair et al (1998) suggest that in natural sciences the number of extracted factors should account for about 95 percent of the total variance; however, in the social sciences, where information is frequently less precise, it is not uncommon to consider a solution that accounts for about 60 percent of the total variance. By applying the extraction criteria, principal components that should be retained include the first four principal components that account for about 73 percent of the total variance. This suggests that the four factors explain about 73 percent of the variation in the 15 original variables.

Table 6. Rotated Component Matrix

System Attribute	Component			
	1	2	3	4
Providing reliable info (X4)	0.885	0.278	0.154	0.111
Working reliably (Xl)	0.640	0.053	0.132	0.173
Providing accurate info (X5)	0.830	0.354	0.146	0.177
Including info need to know (X2)	0.752	0.334	0.099	0.191
Reporting incidents soon (X6)	0.713	0.255	0.222	0.152
Reporting frequently enough (X7)	0.517	0.307	0.429	-0.409
Giving expected length of delays (Xl 3)	0.142	0.857	0.164	-0.022
Specific to commute (X3)	0.255	0.728	0.008	-0.116
Giving reasons for delays (X12)	0.302	0.722	0.349	0.151
Providing info on demand (X14)	0.234	0.572	-0.011	0.244
Easy to use (X8)	0.112	0.155	0.910	0.046
Convenient to use (X9)	0.102	0.100	0.895	0.145
Catching my attention (Xl 0)	0.242	0.039	0.778	-0.123
Distraction (values in reverse order) (Xl 1)	0.327	-0.047	-0.027	0.792
Suggesting alternate routes (Xl 5)	0.229	0.426	0.154	0.604

Rotation Method: Varimax with Kaiser Normalization.

A useful tool in interpreting principal components is component rotation. The component rotation can be described as process of adjusting the principal component axes to achieve a more meaningful component solution. There are several rotation techniques available to rotate the principal components such as varimax and quartimax. In this study, varimax method will be used, because this approach provides a clearer separation of the components (Hair et al, 1998). The output of component rotation is the rotated component matrix, as contained in Table 6. The result reveals that there are four clusters of variables as follows.

- Component 1 is largely correlated with six variables as reflected by the higher factor loadings that indicate the degree of correlation between each variable and the factor. The variables include Providing Reliable Info (X4) (0.885), Working Reliably (X1) (0.840), Providing Accurate Info (X5) (0.830), Including Info Need to Know (X2) (0.752), Reporting Incidents Soon (X6) (0.713), and Reporting Frequently Enough (X7) (0.517). These six system attributes are mostly related with system reliability factor.
- Component 2 is highly correlated with four system attributes: Giving Expected Length of Delays (X13) (0.857), Specific to Commute (X3) (0.728), Giving Reasons for Delays (X12) (0.722), and Providing Info on Demand (X14) (0.572). These four variables are representing information or targeting factor.
- Component 3 is considerably correlated with three variables: Easy to Use (X8) (0.910), Convenient to Use (X9) (0.895), and Catching My Attention (X10) (0.778). The third component can be referred as human factor, because it includes convenient to use, easy to use, and catching my attention measures.
- Component 4 is largely related with Distraction (X11) (0.792) and Suggesting Alternate Routes (X15) (0.604). This last component is related with distraction factor.

Since one of the main purposes of using component scores for the regression analysis in estimating the driver’s satisfaction in the use of various experimental traffic information systems is for creating smaller set of uncorrelated measures to replace the original set of system attributes, it is desirable to estimate component score for each case. Component scores are composite measures created for each observation on each principal component extracted in the PCA. The mathematical formula to calculate the component scores is presented in equation (1). The component scores will be used in the subsequent analysis to represent the value of the components.

Another method of combining several variables that measures the same concept into a single variable is summated score. For example, the total score or the average of the separate variables are usually used as a single variable in the analysis. The main difference between component score and summated scale is that the component score is calculated based on the factor loadings of all variables in the component, while summated scale is calculated by combining only chosen variables. There are several advantages of using the component scores rather than summated scale or original system attributes in estimating the driver’s satisfaction as measured by the driver’s perception on the system performance. First, the components represent a linear combination of the original variables and explain a maximum amount of the variance from the original ones. Second, the rotated components can be orthogonal, meaning that the retained components are uncorrelated. It is a useful feature of the approach particularly in addressing multicollinearity problems in such multivariate analysis.

2.3 Regression Analysis

The second main step of the development of the evaluation model for the Direct traffic information system is to perform the regression analysis. In the analysis the four principal component scores generated by PCA will be treated as explanatory variables in predicting the driver's satisfaction. The satisfaction variables are measured by the driver's perception on the nine system benefits: Satisfied Need for Information (Y_1), Helped Make Better Choices (Y_2), Made Commute Less Stressful (Y_3), Reduced Driving Time (Y_4), Made Driving Time More Certain (Y_5), Made Arrival Time More Certain (Y_6), Helped Avoid Congestion (Y_7), Helped Avoid Unexpected Delays (Y_8), and Improved Commute (Y_9). The nine dependent variables will be regressed on the four principal components that can be formulated in the following regression equations.

$$
\begin{aligned}
Y_1 &= \hat{\alpha}_1 + \hat{\beta}_{11} F_1 + \hat{\beta}_{12} F_2 + \hat{\beta}_{13} F_3 + \hat{\beta}_{14} F_4 + \upsilon_1 && \ldots\ldots\ldots\ldots (2)\\
Y_2 &= \hat{\alpha}_2 + \hat{\beta}_{21} F_1 + \hat{\beta}_{22} F_2 + \hat{\beta}_{23} F_3 + \hat{\beta}_{24} F_4 + \upsilon_2\\
Y_3 &= \hat{\alpha}_3 + \hat{\beta}_{31} F_1 + \hat{\beta}_{32} F_2 + \hat{\beta}_{33} F_3 + \hat{\beta}_{34} F_4 + \upsilon_3\\
Y_4 &= \hat{\alpha}_4 + \hat{\beta}_{41} F_1 + \hat{\beta}_{42} F_2 + \hat{\beta}_{43} F_3 + \hat{\beta}_{44} F_4 + \upsilon_4\\
Y_5 &= \hat{\alpha}_5 + \hat{\beta}_{51} F_1 + \hat{\beta}_{52} F_2 + \hat{\beta}_{53} F_3 + \hat{\beta}_{54} F_4 + \upsilon_5\\
Y_6 &= \hat{\alpha}_6 + \hat{\beta}_{61} F_1 + \hat{\beta}_{62} F_2 + \hat{\beta}_{63} F_3 + \hat{\beta}_{64} F_4 + \upsilon_6\\
Y_7 &= \hat{\alpha}_7 + \hat{\beta}_{71} F_1 + \hat{\beta}_{72} F_2 + \hat{\beta}_{73} F_3 + \hat{\beta}_{74} F_4 + \upsilon_7\\
Y_8 &= \hat{\alpha}_8 + \hat{\beta}_{81} F_1 + \hat{\beta}_{82} F_2 + \hat{\beta}_{83} F_3 + \hat{\beta}_{84} F_4 + \upsilon_8\\
Y_9 &= \hat{\alpha}_9 + \hat{\beta}_{91} F_1 + \hat{\beta}_{92} F_2 + \hat{\beta}_{93} F_3 + \hat{\beta}_{94} F_4 + \upsilon_9
\end{aligned}
$$

Where $Y_1, Y_2, \ldots, Y_9$ are dependent variables. $\hat{\alpha}_1, \hat{\alpha}_2, \ldots, \hat{\alpha}_9$ and $\hat{\beta}_{11}$, $\hat{\beta}_{12}, \ldots, \hat{\beta}_{94}$ denote estimated regression coefficients. υ_1, $\upsilon_1, \ldots$, υ_9 are random disturbances which measure the discrepancy between the actual and the predicted value of the dependent variable. F_1, F_2, F_3, and F_4 represent prinpical components.

Table 7. Sample Descriptive Statistics for the Dependent Variables

Dependent Variable	Mean	Std	Coefficient of variation (V) *
Satisfied need for information (Yl)	2.327	1.361	0.585
Helped make better choices (Y2)	2.724	1.456	0.534
Made commute less stressful (Y3)	2.582	1.235	0.478
Reduced driving time (Y4)	2.592	1.291	0.498
Made driving time more certain (Y5)	2.520	1.270	0.504
Made arrival time more certain (Y6)	2.520	1.262	0.501
Helped avoid congestion (Y7)	2.704	1.386	0.513
Helped avoid unexpected delays (Y8)	2.704	1.408	0.521
Improved commute (Y9)	2.643	1.364	0.516

Scale

1 = strongly disagree, 2 = somewhat disagree, 3 = neither 4 = somewhat agree, and 5 = strongly agree

) Coefficient **of variation = (std/mean).*

The descriptive statistics for the 9 dependent variables are presented in Table 7. These variables can be interpreted as direct measures of the driver's perception on the Direct traffic information system benefits. The all system variables have the same scale in which 1 represents strongly disagree and 5 represents strongly agree. The sample size is 98 observations with the sample means for these variables ranging from the largest (2.520) for Made Driving Time More Certain (Y5) and Made Arrival Time More Certain (Y6) to the smallest (2.724) for Helped Make Better Choices (Y2). The variability of the measurements as reflected by the standard deviations range from 1.235 for Made Commute Less Stressful (Y3) to 1.456 for Helped Make Better Choices (Y2). The coefficients of variation, as another variability measure of the data, extend from the smallest (0.478) for Made Commute Less Stressful (Y3) to the largest (0.585) for Satisfied Need for Information (Yl), implying that data of the latter is more dispersed than that of the former. Similar to the system attributes data, the descriptive statistics of the system benefits do not indicate over-dispersion in the raw data.

The results of the regression analysis for the models given in the equation (2) appear in Table 8. As measured by the percent of variance explained, the regression analysis is relatively successful. The proportion of variation of the nine driver's satisfaction variables explained by the models, as listed in the last column labeled R2, is ranging from 53.4 percent Made Driving Time More Certain (Y5) to 65.8 percent for Satisfied Need for Information (Y1). The proportions of variance explained by the model might be considered as a reasonable value particularly for such social sciences case where information is frequently less decisive. The coefficients of the four explanatory variables are positively significant varying from the 0.1 percent to 5 percent significant level. It means that as expected the four explanatory variables have positive influence in determining the satisfaction variables.

Table 8. Regression Analysis of the Driver's Satisfaction

Dependent Variable	Coefficient					R2
	Constant	Component 1	Component 2	Component 3	Component 4	
Satisfied need for information (Y1)	-0.390	1.244	0.352	0.278	0.213	0.658
	(0.402)	(0.118) ***	(0.058) ***	(0.075) ***	(0.213) * **	
Helped make better choices (Y2)	-0.426	1.230	0.374	0.336	0.272	0.612
	(0.461)	(0.136) ***	(0.067) ***	(0.086) ***	(0.073) ***	
Made commute less stressful (Y3)	-0.275	0.841	0.364	0.284	0.260	0.549
	(0.418)	(0.123) ***	(0.061) ***	(0.078) ***	(0.066) ***	
Reduced driving time (Y4)	-0.393	0.926	0.357	0.356	0.176	0.551
	(0 440)	(0.130) ***	(0.064) ***	(0.082) ***	(0.070) **	
Made driving time more certain (Y5)	-0.047	0.929	0.363	0.249	0.191	0.538
	(0.433)	(0.128) ***	(0.063) ***	(0.081) ***	(0.069) **	
Made arrival time more certain (Y6)	-0.065	0.918	0.352	0.266	0.181	0.534
	(0.432)	(0.127)***	(0.063) ***	(0.081) ***	(0.069) **	
Helped avoid congestion (Y7)	-0.057	1.067	0.417	0.207	0.236	0.561
	(0.465)	(0.137) ***	(0.067) ***	(0.087) *	(0.074) l **	
Helped avoid unexpected delays (Y8)	0.108	1.080	0.403	0.213	0.217	0.535
	(0.486)	(0.143) ***	(0.071) ***	(0.091)*	(0.077) l *	
Improved commute (Y9)	-0.345	1.151	0.371	0.310	0.250	0.628
	(0.422)	(0.124) ***	(0.061) ***	(0.079) ***	(0.067) ***	

Note:

*() denotes standard error. The level of significant of the coefficients is indicated by * for the 5% level,*
*"for the 1% level, and *** for the 0.1% level*

Another interesting result shows that principal component 1 which is mostly related with reliability aspects of the system such as Working Reliably (X1) and Providing Accurate Info (X5) is the most important factor in determining the driver's satisfaction, as reflected by the highest significant coefficient of the variable across all regression models. The component 1's coefficient ranges from 0.841 for Made Commute Less Stressful (Y3) to 1.244 for Satisfied Need for Information (Y1). It also suggests that the first explanatory variable has higher impact in determining the level of driver's satisfaction in providing need for information than in reducing the driver's stress during their commute. The evidence also shows that the first independent variable has considerable impact in influencing the driver's satisfaction in helping make better choice (Y2), avoiding unexpected delays (Y8), and improving commute (Y9) as reflected by coefficients of the variable greater than one. These results suggest that the first principal component which is mostly related with reliability system attributes is the most important determinant of the driver's satisfaction indicators.

With respect to the second principal component which is largely associated with information targeting such as Giving Expected Length of Delays (X13), Specific to Commute (X3), Giving Reasons for Delays (X12), and Providing Info on Demand (X14), it is observed that the component has important influence in helping avoid congestion (Y7) and unexpected delays (Y8), as indicated by the higher coefficients of the component in the two outcome variables equations, 0.417 and 0.403, respectively. The third principal component which is referred as a human factor-related aspect has higher impact in affecting the level of driver's satisfaction in helping make better choices (Y2) (0.336), reducing driving time (Y4) (0.356), and improving commute (Y9) (0.310) than the other driver's satisfaction indicators. The last principal component which is largely associated with Distraction (values in reverse order) (X11) and Suggesting Alternate

Routes (X15) has larger influence in determining the satisfaction in helping make better choices (Y2) (0.272), making commute less stressful (Y3) (0.260), and improving commute (Y9) (0.250) than the remaining dependent variables.

In order to estimate the driver's satisfaction, we will apply the fitted regression equations as presented in Table 8 on the four components scores which are generated by the PCA in the previous analysis to produce the predicted values of the driver's satisfaction indicators. We can command SAS or SPSS to produce the predicted values when we regress the satisfaction variables on the four principal component scores. The estimation of the satisfaction variables will be calculated with two different conditions, without and with controlling reliability attribute of the four systems being investigated and the control group. The estimates means of the dependent variables by system without controlling the reliability are shown in Table 9.

As shown in table, the control group has the highest level of satisfaction in the first three outcome variables (3.00, 3.44, and 3.08, respectively) and the ninth outcome variable (3.29), while, the RDS/SCA has the highest values of the driver's satisfaction variables for the fourth through the eighth variables (3.21, 3.08, 3.09, 3.28, and 3.29, respectively). However, the differences between the two traffic information systems' performance are small, it might suggest that without controlling reliability aspect of the systems the driver's satisfaction as measured by their perception on the radio (control group) and the RDS/SCA systems are about the same. Another interesting result reveals that the drivers perceived that the phone system has the lowest level of performance, as reflected by the smallest mean values of the estimates of the 9 dependent variables. The evidence also shows that LPHAR has better performance than AHAR in the driver's satisfaction variables. The last column labeled 'Total' presents the overall means of the outcome variables by traffic information system. The system performance of the control group and the RDS/SCA are above the overall means, whereas the performance of the remaining systems are below the grand means (See Table 9).

Table 9. The Means of the Estimated Driver's Satisfaction Variables by Traffic Information System

Dependent Variable	Traffic formation System					Total
	Control	AHAR	LPHAR	PHONE	RDS/SCA	
Satisfied need for information	3.00	1.85	2.19	1.64	2.99	2.35
Helped make better choices	3.44	2.21	2.59	2.03	3.37	2.74
Made commute less stressful	3.08	2.16	2.54	2.14	3.06	2.61
Reduced driving time	3.12	2.25	2.44	2.00	3.21	2.62
Made driving time more certain	3.01	2.14	2.45	2.03	3.08	2.55
Made arrival time more certain	3.02	2.16	2.43	2.01	3.09	2.55
Helped avoid congestion	3.24	2.22	2.68	2.20	3.28	2.73
Helped avoid unexpected delays	3.24	2.24	2.66	2.18	3.29	2.73
Improved commute	3.29	2.16	2.52	2.00	3.26	2.66

Scale

1 = strongly disagree 2 = somewhat &agree, 3 = nnther, 4 = somewhat agree, and 5 = strongly agree

The evaluation model is designed to measure the driver's satisfaction that allows us to control reliability attribute of the systems by setting the reliability equal across the systems being investigated and the control group (radio system). As noted above, the four experimental traffic information systems are designed without standard operations and maintenance support. As results, the systems did not operate at high levels of reliability. Unfortunately, the evidence shows that low levels of operational reliability as reflected by Working Reliably (Xl) indicator affected the subject appreciation of the system features and capabilities. By controlling the reliability aspect of the systems, the other important system features affecting the system capabilities can be identified.

What we meant with controlling reliability in this study is that the reliability indicator as reflected by original system attribute of System Works Reliably (Xl) will be set equal (at the maximum scale of 5) across the systems. The estimates means of the driver's satisfaction indicators with controlling the reliability of the systems are presented in Table 10.

With controlling the reliability the RDS/SCA has the highest scores across the all satisfaction indicators among the five. It suggests that if the systems were perfectly reliable, the RDS/SCA becomes the most preferred system among the competing traffic information systems. Without controlling the reliability, the respondents perceived no difference whether or not using the RDS/SCA. It is indicated by the scores about 3 (neither) for the nine satisfaction indicators, ranging from 2.99 for 'Satisfied need for info' to 3.37 for 'Helped make batter choices'. However, if we were able to control the reliability the system the scores increase from about 3 (neither) to 4 (somewhat agree), extending from 3.50 for 'Made commute less stressful' to 4.09 for 'Helped make better choices'. The radio system (control group) still indicates better performances than the other three competing systems, AHAR, LPHAR, and Phone with controlling the reliability.

Table 10. The Means of the Estimated Driver's Satisfaction Variables by Traffic Information System with controlling Reliability Aspect of the Systems

Dependent Variable	Traffic Information System					Total
	Control	AHAR	LPHAR	PHONE	RDS/SCA	
Satisfied need for information	3.35	2.92	3.09	2.73	3.73	3.18
Helped make better choices	3.77	3.24	3.46	3.08	4.09	3.54
Made commute less stressful	3.28	2.79	3.06	2.77	3.50	3.09
Reduced driving time	3.35	2.96	3.03	2.73	3.71	3.17
Made driving time more certain	3.25	2.86	3.06	2.77	3.58	3.11
Made arrival time more certain	3.25	2.87	3.04	2.75	3.59	3.11
Helped avoid congestion	3.52	3.06	3.39	3.06	3.87	3.39
Helped avoid unexpected delays	3.53	3.10	3.38	3.06	3.89	3.40
Improved commute	3.60	3.10	3.32	2.97	3.92	3.39

Scale

1 = strongly disagree, 2 = somewhat disagree, *3 = neither, 4 =* somewhat *agree, and 5 = strongly agree*

The comparison analysis between "without" and "with" controlling the reliability for the nine outcome variables is presented in Figures 2-10. The lower line indicates system benefits without controlling the reliability, while the upper line denotes the system benefits if we were able to perfectly control the reliability. In general, without controlling the reliability the performances of the two systems, RDS/SCA and the radio (control) are about the same. However, if we were able to perfectly control the system reliability RDS/SCA indicates as the most preferred system. The figures reveal that there is considerable improvement of the nine outcome indicators across the all systems if we were able to perfectly control the reliability. For example, for Satisfied Need for Information (Y_1) the improvement extends from 0.35 (3.35-3.00) for control group to 1.09 (2.73-1.64) for Phone system (see Figure 2). Similarly, for Improved Commute (Y_9) the improvement is ranging from the smallest of 0.31 (3.60-3.29) for the control group and the largest of 0.97 (2.97-2.00) for Phone system (see Figure 10).

Figure 2

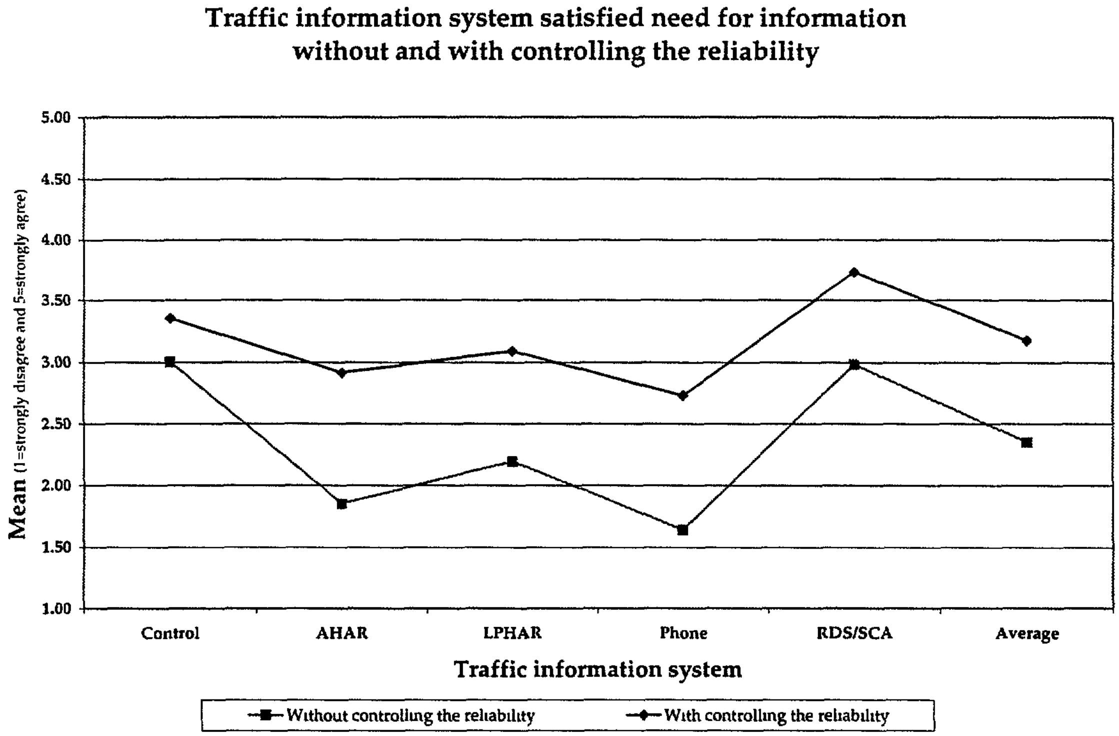

Traffic information system satisfied need for information without and with controlling the reliability

Figure 3

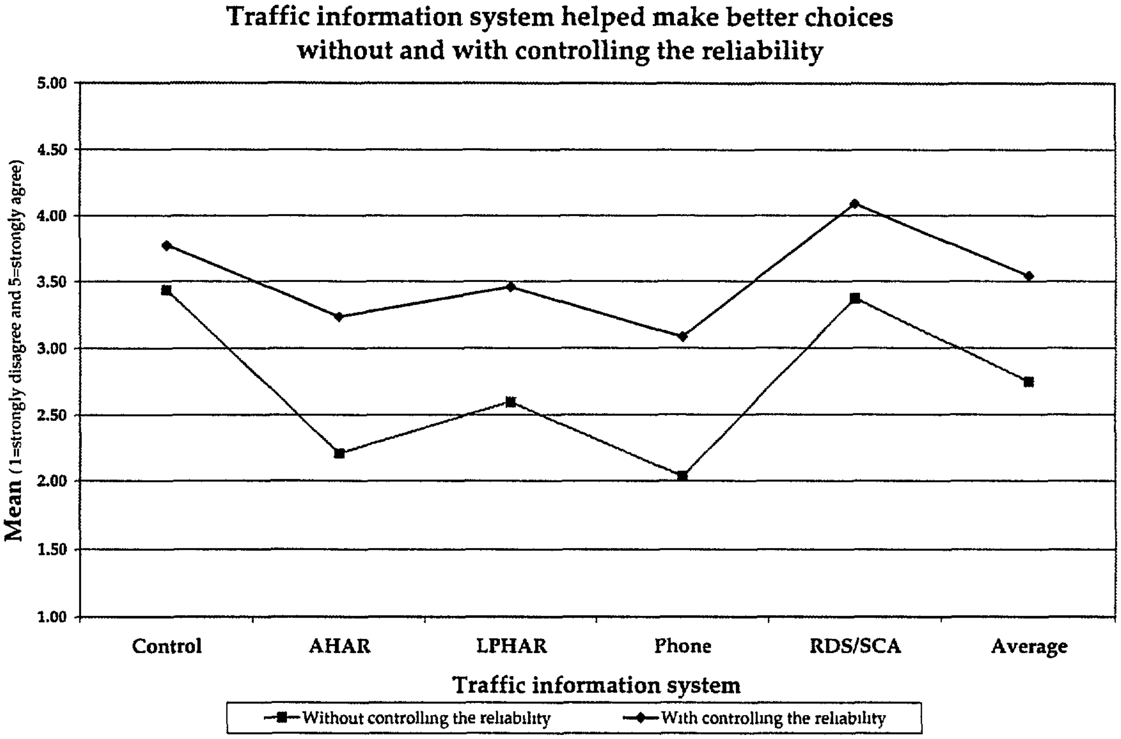


Figure 4

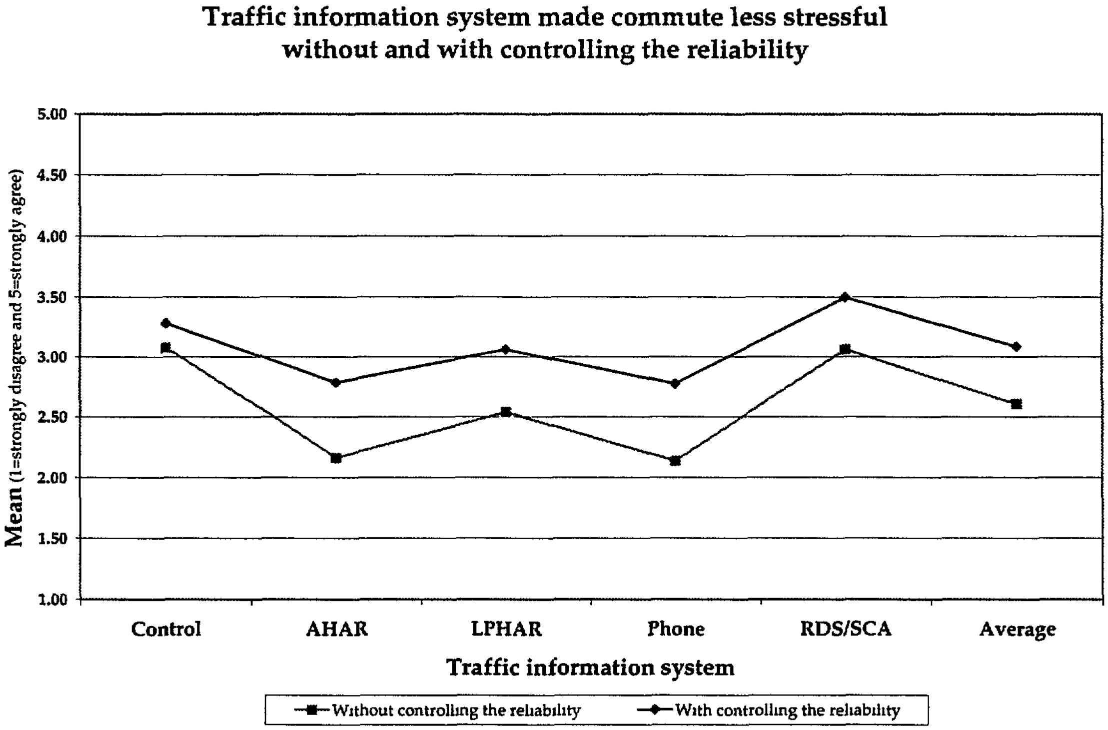


Figure 5

Traffic information system reduced driving time without and with controlling the reliability

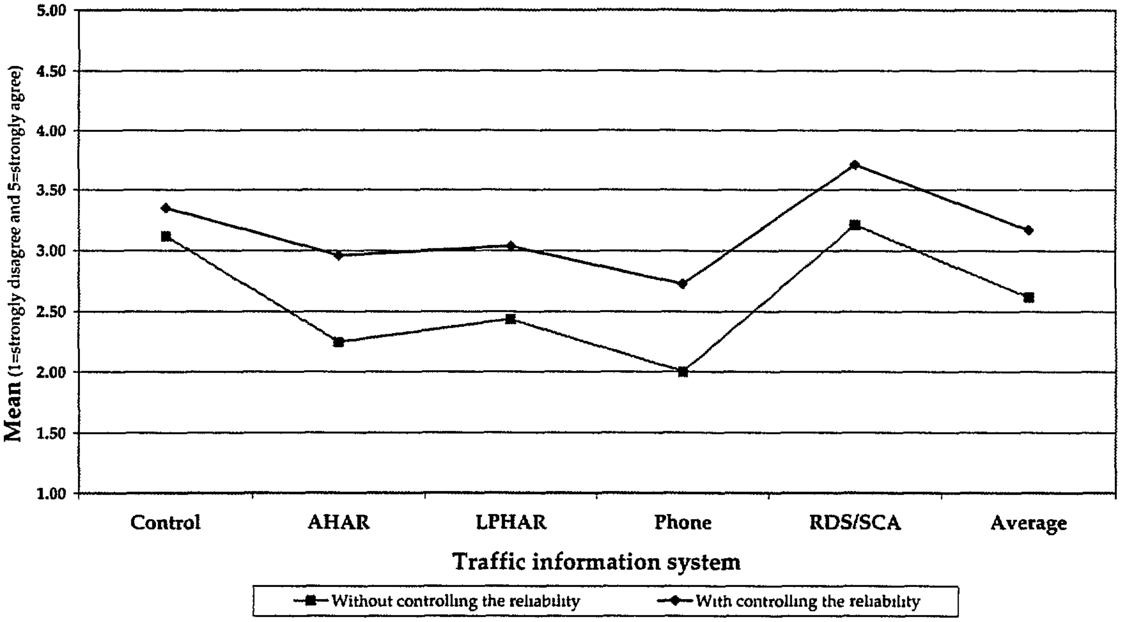


Figure 6

Traffic information system made driving time more certain without and with controlling the reliability

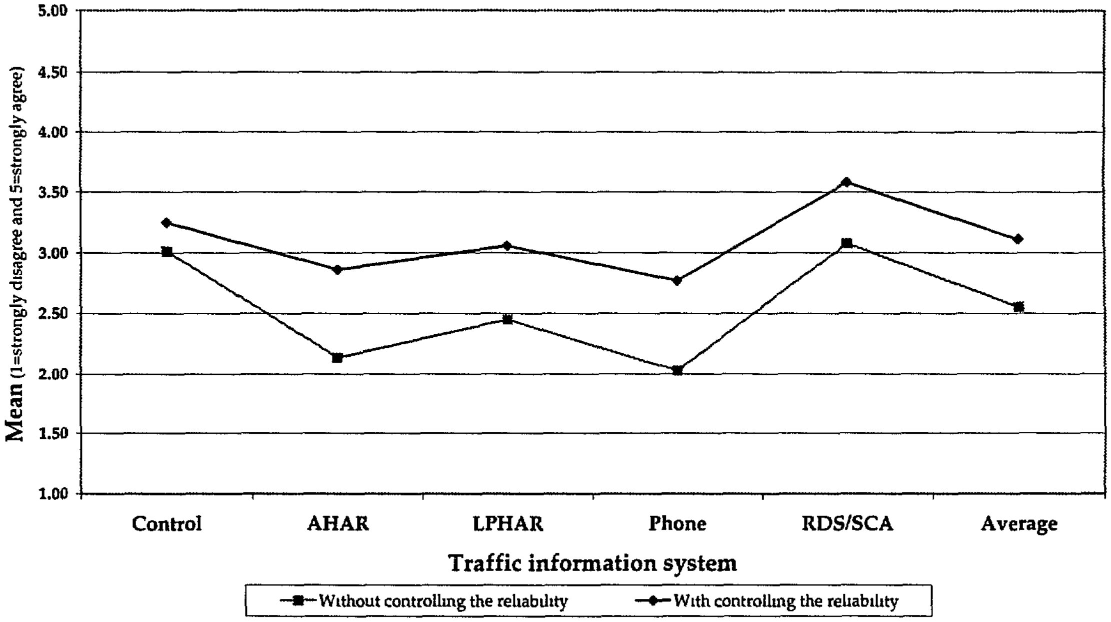


Figure 7

Traffic information system made arrival time more certain without and with controlling the reliability

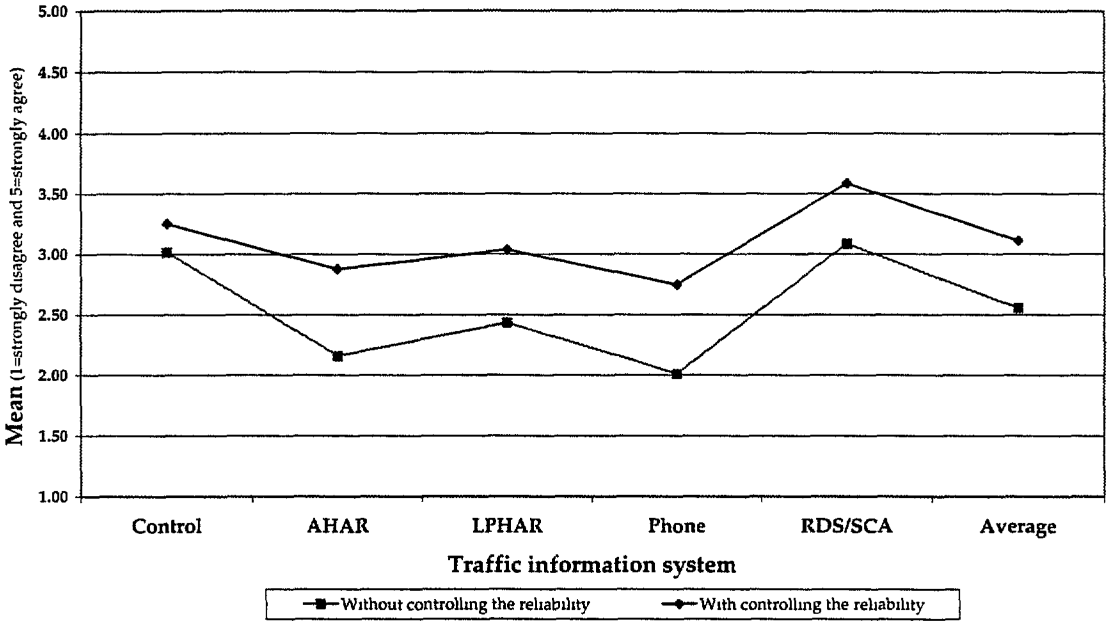


Figure 8

Traffic information system helped avoid congestion without and with controlling the reliability

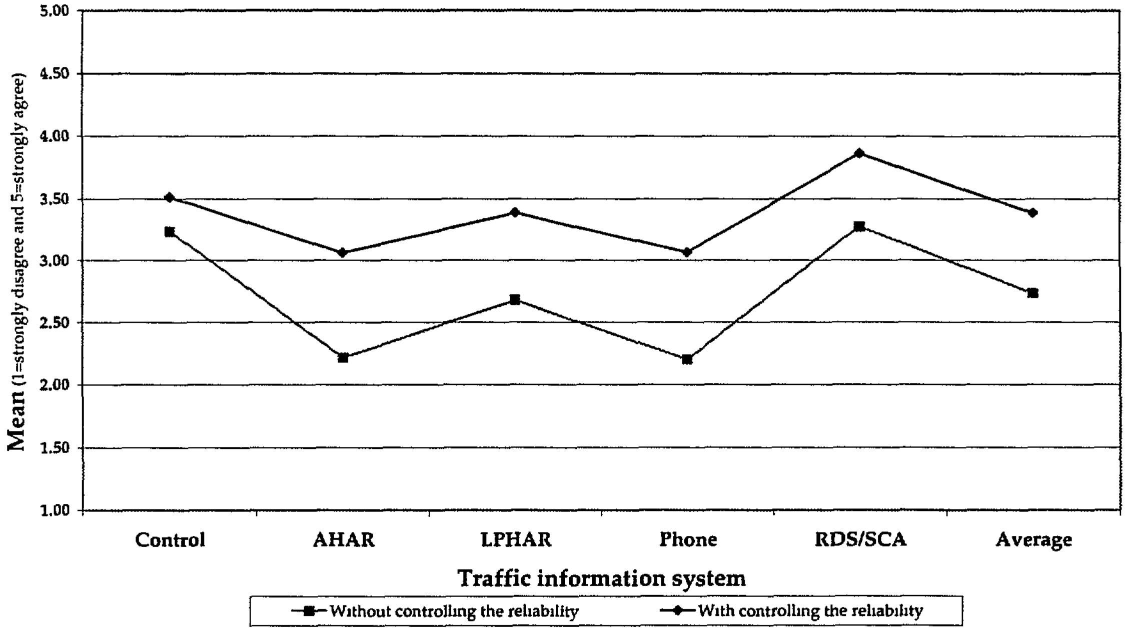


Figure 9

Traffic information system helped avoid unexpected delays without and with controlling the reliability

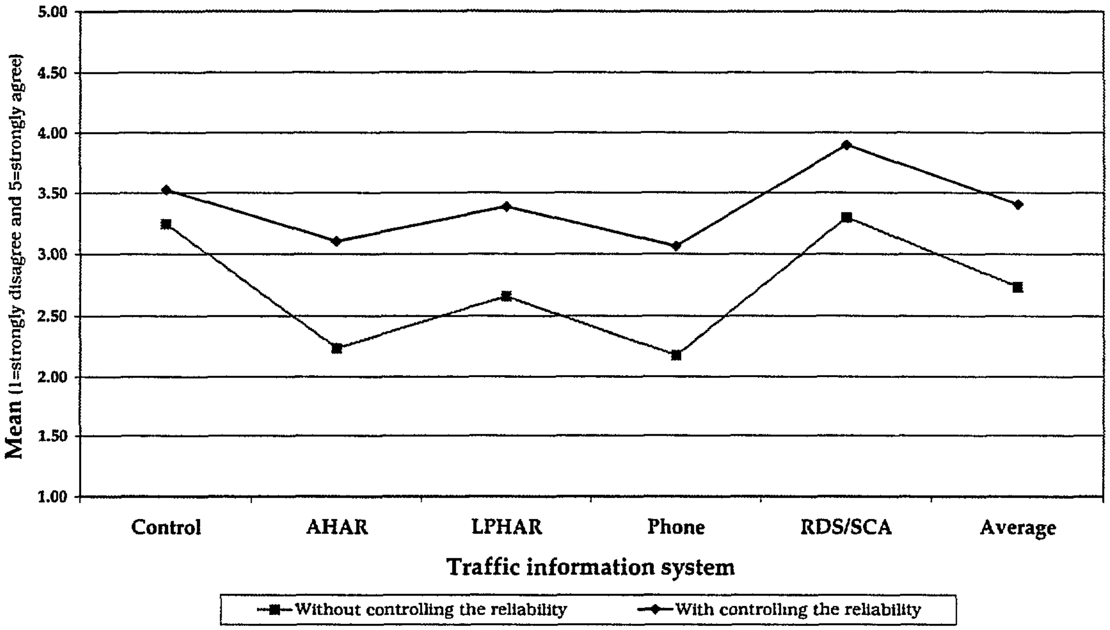
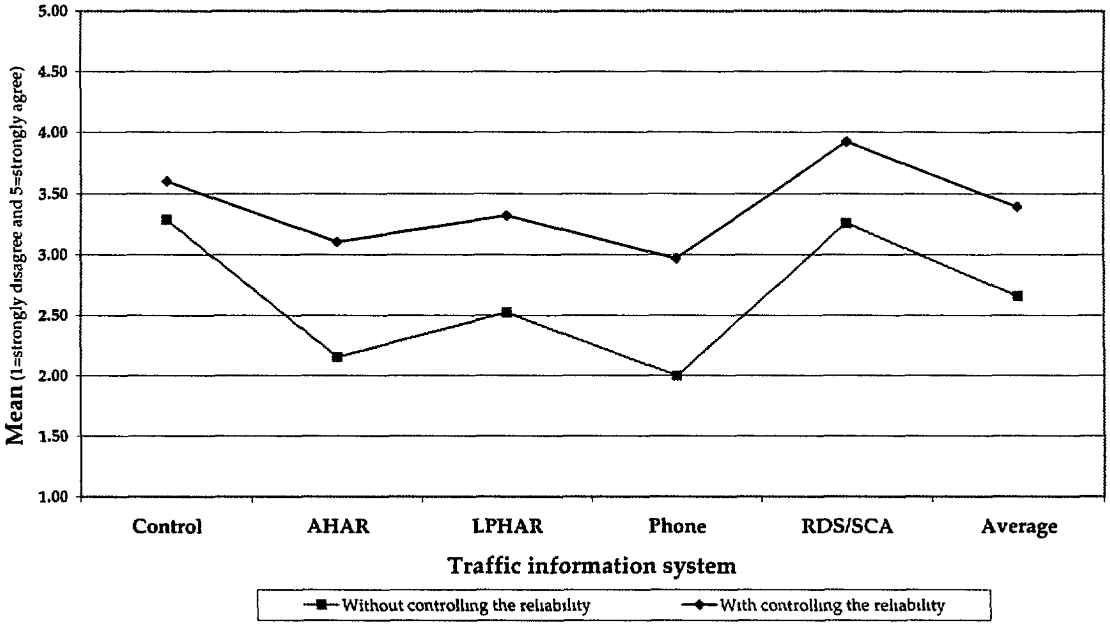


Figure 10

Traffic information system improved commute without and with controlling the reliability

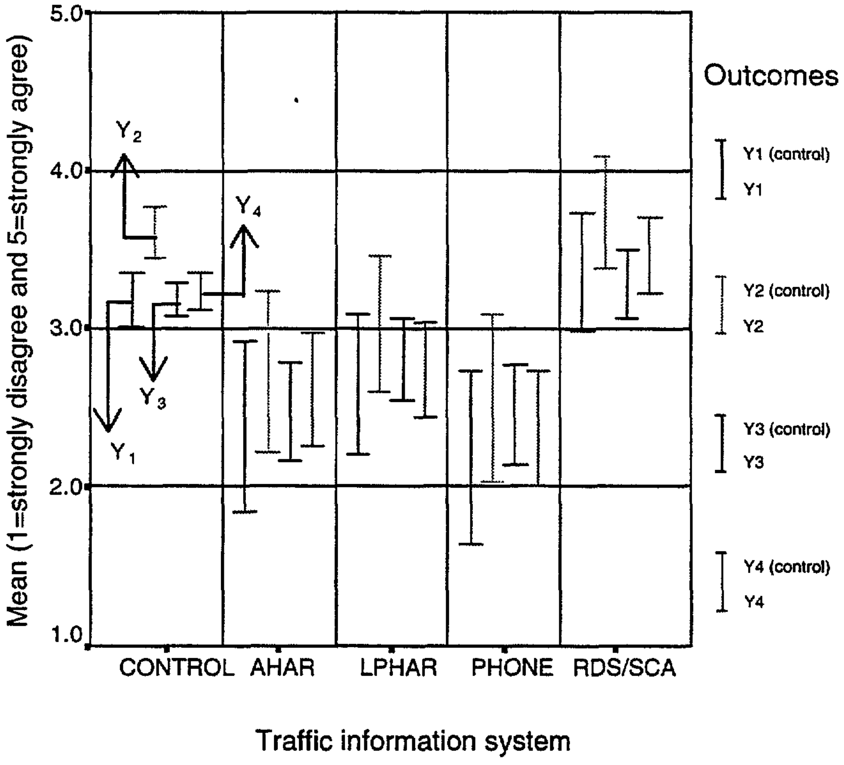


The summary of the difference between with and without controlling the reliability for the nine outcome variables by traffic information system is shown in Figures 11 and 12. Figure 11 contains the first four outcome variables, Satisfied Need for Information (Y_1) through Reduced Driving Time (Y_4). Figure 12 contains the last five outcome variables, Made Driving Time More Certain (Y_5) through Improved Commute (Y_9). Each line represents the difference in each outcome variable between with and without controlling the reliability. The upper point of each line denotes value of outcome variable with controlling the reliability, and the lower point indicates the value of corresponding variable without controlling the reliability.

Each line can be interpreted as the degree of potential improvement for each outcome variable that corresponding traffic information system can achieve if we were able to control the reliability. The two figures suggests that if the systems were perfectly reliable, the four experimental traffic information systems have higher improvement than the control group (radio traffic information system) for the nine benefit indicators as reflected by the longer lines.

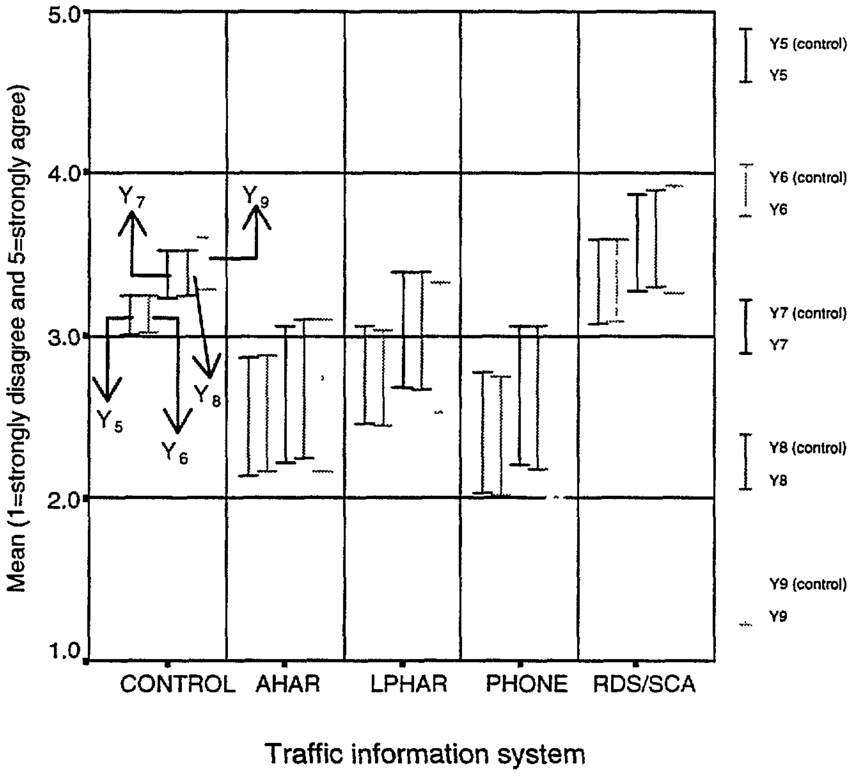
Figure 11

The difference between with and without controlling the reliability for Satisfied Need for Information (Y_1) through Reduced Driving Time (Y_4) by traffic information system



Note: Satisfied Need for Information (Y_1) Made Commute Less Stressful (Y_3)
Helped Make Better Choices (Y_2) Reduced Driving Time (Y_4)

Figure 12
The difference between with and without controlling the reliability for Made Driving Time More Certain (Y_5) through Improved Commute (Y_9) by traffic information system



Note: Made Driving Time More Certain (Y_5)
Made Arrival Time More Certain (Y_6)
Helped Avoid Congestion (Y_7)
Helped Avoid Unexpected Delays (Y_8)
Improved Commute (Y_9)

The results of paired samples test for the nine outcome variables of the five traffic information systems are presented in Tables 1 I-15. The main purpose of the analysis is to test whether there is significant mean difference in outcome variable between with and without controlling reliability. The first column, labeled ‘Variable’, represents the difference in the ith outcome variable between with and without controlling the reliability, where Y,’ denotes mean value of the ith outcome variable with controlling the reliability, and Yi denotes mean value of the ith outcome variable without controlling the reliability. The third column labeled ‘Mean’ indicates the mean difference in the outcome variable between with and without controlling the reliability. This column also can be interpreted as the improvement gained for the outcome variables when we were able to perfectly control the reliability.

The paired test analysis shows that there are significant mean differences between with and without controlling the reliability for all nine outcome indicators of the five traffic information systems, as indicated by the 0.1% significant level and the positive values of the lower and upper points with the 95% confidence interval of the difference (see Tables 11-l 5). An interesting finding reveals that the four experimental traffic information systems gained higher improvement than the control group for the nine outcome variables. For example, the improvements of the nine outcome variables gained for the control group are ranging from 0.204 for Made Commute Less Stressful (Y3) to 0.350 for Satisfied Need for Information (Y1) (see Table 1 I). Similarly, the improvements gained for AHAR and RDS/SCA range from 0.623 for Made Commute Less Stressful (Y3) to 1.066 for Satisfied Need for Information (Y1), and from 0.434 for Made Commute Less Stressful (Y3) and 0.744 for Satisfied Need for Information (Y1), respectively (see Tables 12 and 15).

Table 11. Paired Samples Test for Control Group

Variable	Description	Paired Differences					t	Sig. (2-tailed)
		Mean	Std	Std. Error Mean	95% CI of the Difference			
					Lower	Upper		
$Y_1' - Y_1$	Satisfied Need for Information	0.350	0.233	0.053	0.237	0.462	6.542	0.000
$Y_2' - Y_2$	Helped Make Better Choices	0.337	0.224	0.051	0.229	0.445	6.551	0.000
$Y_3' - Y_3$	Made Commute Less Stressful	0.204	0.137	0.031	0.138	0.269	6.491	0.000
$Y_4' - Y_4$	Reduced Driving Time	0.233	0.156	0.036	0.158	0.308	6.508	0.000
$Y_5' - Y_5$	Made Driving Time More Certain	0.236	0.159	0.036	0.160	0.313	6.485	0.000
$Y_6' - Y_6$	Made Arrival Time More Certain	0.235	0.158	0.036	0.159	0.311	6.492	0.000
$Y_7' - Y_7$	Helped Avoid Congestion	0.278	0.185	0.042	0.190	0.367	6.578	0.000
$Y_8' - Y_8$	Helped Avoid Unexpected Delays	0.282	0.190	0.043	0.191	0.373	6.484	0.000
$Y_9' - Y_9$	Improved Commute	0.312	0.207	0.048	0.212	0.412	6.565	0.000

Note: $(Y_i'-Y_i)$ denotes the mean difference in the i th dependent variable between with and without controlling reliability

Table 12. Paired Samples Test for AHAR

Variable	Description	Paired Differences					t	Sig. (2-tailed)
		Mean	Std	Std. Error Mean	95% CI of the Difference			
					Lower	Upper		
$Y_1' - Y_1$	Satisfied Need for Information	1.066	0.320	0.073	0.911	1.220	14.519	0.000
$Y_2' - Y_2$	Helped Make Better Choices	1.027	0.308	0.071	0.879	1.175	14.538	0.000
$Y_3' - Y_3$	Made Commute Less Stressful	0.623	0.187	0.043	0.532	0.713	14.484	0.000
$Y_4' - Y_4$	Reduced Driving Time	0.713	0.214	0.049	0.609	0.816	14.492	0.000
$Y_5' - Y_5$	Made Driving Time More Certain	0.723	0.218	0.050	0.618	0.828	14.467	0.000
$Y_6' - Y_6$	Made Arrival Time More Certain	0.718	0.216	0.050	0.614	0.822	14.483	0.000
$Y_7' - Y_7$	Helped Avoid Congestion	0.845	0.253	0.058	0.723	0.967	14.545	0.000
$Y_8' - Y_8$	Helped Avoid Unexpected Delays	0.863	0.260	0.060	0.738	0.989	14.477	0.000
$Y_9' - Y_9$	Improved Commute	0.948	0.284	0.065	0.811	1.085	14.534	0.000

Note: $(Yi'-Yi)$ denotes the mean difference in the i th dependent variable between with and without controlling reliability

Table 13. Paired Samples Test for LPHAR

Variable	Description	Paired Differences					t	Sig. (2-tailed)
		Mean	Std	Std. Error Mean	95% CI of the Difference			
					Lower	Upper		
$Y_1' - Y_1$	Satisfied Need for Information	0.895	0.364	0.086	0.714	1.076	10.440	0.000
$Y_2' - Y_2$	Helped Make Better Choices	0.863	0.350	0.083	0.689	1.037	10.459	0.000
$Y_3' - Y_3$	Made Commute Less Stressful	0.524	0.213	0.050	0.418	0.630	10.441	0.000
$Y_4' - Y_4$	Reduced Driving Time	0.598	0.244	0.057	0.477	0.719	10.404	0.000
$Y_5' - Y_5$	Made Driving Time More Certain	0.609	0.248	0.058	0.485	0.732	10.414	0.000
$Y_6' - Y_6$	Made Arrival Time More Certain	0.604	0.246	0.058	0.482	0.726	10.416	0.000
$Y_7' - Y_7$	Helped Avoid Congestion	0.710	0.288	0.068	0.567	0.854	10.468	0.000
$Y_8' - Y_8$	Helped Avoid Unexpected Delays	0.726	0.296	0.070	0.579	0.873	10.412	0.000
$Y_9' - Y_9$	Improved Commute	0.798	0.323	0.076	0.638	0.959	10.475	0.000

Note: (Yi'-Yi) denotes the mean difference in the i th dependent variable between with and without controlling reliability

Table 14. Paired Samples Test for PHONE

Variable	Description	Paired Differences					t	Sig. (2-tailed)
		Mean	Std	Std. Error Mean	95% CI of the Difference			
					Lower	Upper		
$Y_1' - Y_1$	Satisfied Need for Information	1.089	0.329	0.078	0.925	1.252	14.020	0.000
$Y_2' - Y_2$	Helped Make Better Choices	1.049	0.317	0.075	0.892	1.207	14.039	0.000
$Y_3' - Y_3$	Made Commute Less Stressful	0.638	0.193	0.045	0.542	0.734	14.034	0.000
$Y_4' - Y_4$	Reduced Driving Time	0.727	0.221	0.052	0.618	0.837	13.980	0.000
$Y_5' - Y_5$	Made Driving Time More Certain	0.740	0.225	0.053	0.629	0.852	13.982	0.000
$Y_6' - Y_6$	Made Arrival Time More Certain	0.734	0.223	0.052	0.624	0.845	14.002	0.000
$Y_7' - Y_7$	Helped Avoid Congestion	0.863	0.261	0.061	0.734	0.993	14.046	0.000
$Y_8' - Y_8$	Helped Avoid Unexpected Delays	0.883	0.268	0.063	0.750	1.016	13.987	0.000
$Y_9' - Y_9$	Improved Commute	0.970	0.293	0.069	0.824	1.116	14.047	0.000

Note: (Yi'-Yi) denotes the mean difference in the i th dependent variable between with and without controlling reliabilty

Table 15. Paired Samples Test for RDS/SCA

Variable	Description	Paired Differences					t	Sig. (2-tailed)
		Mean	Std	Std. Error Mean	95% CI of the Difference			
					Lower	Upper		
$Y_1' - Y_1$	Satisfied Need for Information	0.744	0.462	0.103	0.527	0.960	7.199	0.000
$Y_2' - Y_2$	Helped Make Better Choices	0.717	0.445	0.099	0.509	0.925	7.212	0.000
$Y_3' - Y_3$	Made Commute Less Stressful	0.434	0.271	0.060	0.307	0.560	7.169	0.000
$Y_4' - Y_4$	Reduced Driving Time	0.497	0.310	0.069	0.352	0.642	7.180	0.000
$Y_5' - Y_5$	Made Driving Time More Certain	0.504	0.315	0.070	0.356	0.651	7.157	0.000
$Y_6' - Y_6$	Made Arrival Time More Certain	0.500	0.312	0.070	0.354	0.646	7.170	0.000
$Y_7' - Y_7$	Helped Avoid Congestion	0.590	0.366	0.082	0.419	0.761	7.218	0.000
$Y_8' - Y_8$	Helped Avoid Unexpected Delays	0.602	0.375	0.084	0.426	0.777	7.166	0.000
$Y_9' - Y_9$	Improved Commute	0.662	0.411	0.092	0.470	0.854	7.208	0.000

Note: (Y_i'-Y_i) denotes the mean difference in the i th dependent variable between with and without controlling reliability

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