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Authors

Chen, Wan-hui
Uwaine, Rochelle
Klaver, Kelley
et al.

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Wan-Hui Chen, Rochelle Uwaine, Kelley Klaver, Ken Kurani, Paul P. Jovanis
University of California, Davis

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ITS Information and Services to Enhance the Mobility of Disabled Travelers

by

Wan-Hui Chen[1], Kelley Klaver[1],
Rochelle Uwaine[1], Ken Kurani[1], and
Paul P. Jovanis[2]

[1]Post-Graduate Research Engineer
Institute of Transportation Studies

[2]Associate Director, Institute of Transportation Studies
Professor, Department of Civil and Environmental Engineering
University of California at Davis

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ABSTRACT

This study examined the potential of advanced information systems to increase the mobility of disabled travelers using public transportation. A stated preference survey inquired as to whether subjects would make more trips by transit, paratransit, and/or real-time paratransit if kiosk, on-board, in-home, and/or personal information systems were available. The results show that these systems do have the potential to increase the use of public transportation by disabled travelers, as they allow for more trip flexibility that what is currently available. Regression and log-linear models show that transit users and those without cars are more likely to use transit if advanced systems were available. Wheelchair users are less likely than non-wheelchair users to use transit with advanced systems.

KEY WORDS

transit, paratransit, real-time paratransit, disabled travelers, ITS, transit information systems, mobility

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EXECUTIVE SUMMARY

A survey was conducted in August and September of 1996 to examine the potential of ITS services and techniques to increase the mobility of elderly (i.e., age 65 or over) and disabled travelers (i.e., under age 65 and with physical and/or communicational disabilities) within the Sacramento area. This is a supplementary report to Chen et al. (1997) and focuses on the perceptions of 118 disabled persons of advanced technologies. The systems presented to them were the on-board, kiosk, in-home, and personal information systems. In addition to these information systems, a real-time paratransit service was introduced. Subjects answered questions regarding their stated increase in transit use as a result of the technologies.

In general, the disabled subjects had positive attitudes toward the proposed advanced information systems. When asked if these information systems would increase their mobility (i.e. making more trips) by using transit alone, or using transit, paratransit, or real-time paratransit, 64% said yes to the on-board and kiosk systems, 73% said yes to the in-home system, and 75% said yes to the personal information system. As for the proposed real-time paratransit service, 77% said they would make more trips with this service.

Logistic regression and log-linear models were used to examine the influential factors affecting the stated increased use of transit by disabled travelers as a result of the information technologies and the real-time paratransit service (i.e. their attitudes towards using transit with advanced technologies). The modeling results show that non-drivers have more positive attitudes than drivers towards increasing their transit trips as a result of all five systems, as they stated they would make more transit trips with the systems available. Transit users have more positive attitudes than non-transit users towards increasing their transit trips as a result of the on-board and kiosk information systems. Non-wheelchair users also have more positive attitudes than wheelchair users towards increasing their transit trips as a result of the on-board and kiosk information systems. Those who completed college or have a higher degree have more positive attitudes than those who did not towards increasing their transit trips as a result of the in-home and personal information systems.

1. INTRODUCTION

One of the main goals of introducing Intelligent Transportation Systems (ITS) is to increase travelers' mobility and accessibility. This report focuses on the disabled population in hopes of recognizing their special needs and developing ITS technologies to increase their mobility.

In a preceding study of elderly and disabled persons, Chen *et al*. (1997) found that there are differences between the two groups in terms of disabilities, trip making characteristics, mode choice, and perceptions of ITS technologies. As a result, separate analyses were conducted and are presented in this report and in "A Survey of the Elderly Travelers: Initial Results from California and Their Applications for ITS" by Abdel-Aty *et al*. (1997).

2. SURVEY RESULTS

A survey within the Sacramento area was completed in August and September of 1996 to examine levels of disabilities, trip-making patterns, and perceptions of advanced information technologies and specialized services for the elderly and disabled. The four advanced information technologies addressed in the survey were on-board, kiosk, in-home, and personal information systems. The specialized service introduced in the survey was real-time paratransit. The sample size included 260 elderly (i.e., age 65 or over) and 118 disabled (i.e., under age 65 and with physical and/or communicational disabilities) persons.

The major differences between the elderly and disabled are as follows (Chen *et al*., 1997):

1. Of the 12 tasks for determining subjects' leg, hand, finger, hearing and speaking limitations, the more difficult tasks for disabled non-wheelchair users are: walking up or down a flight of stairs, standing for more than 15 minutes at a time, standing outside when it is very hot or cold, and reaching for objects higher than six feet. On the other hand, elderly non-wheelchair subjects have only slight difficulties. Wheelchair users of all ages have the most difficulty traveling three blocks without resting, picking up objects from the floor, carrying a bag of groceries, and reaching for objects higher than six feet. The various limitations for the disabled and wheelchair user groups should be considered when transportation services are designed.
2. The majority of the elderly are retired (95%) and are non-transit (81%) and non-paratransit (98%) users. The majority of the disabled are employed (81%) and are transit (72%) users, while a relatively small percent (35%) are paratransit users.

3. A larger percentage of elderly persons (89%) than disabled persons (14%) currently drive. The elderly drive for all trip purposes while the disabled take transit or paratransit for work/school trips, and ride as passengers in private automobiles for trips other than work/school. This strongly indicates that the disabled are largely dependent on others when making discretionary trips.
4. The disabled make more work/school trips than the elderly; however, the elderly make nearly twice as many shopping and errand trips than the disabled.
5. Unlike the elderly, the disabled perceive that the four advanced information systems will increase their mobility (based on their stated increase in transit use with the systems). As for the real-time paratransit service, both the elderly and disabled state that the real-time paratransit service will increase their mobility.
6. Among the four information systems, the disabled consider the personal system to be the most useful (55%), while the elderly consider the personal (26%) and in-home (29%) systems to be most useful.

3. ADVANCED TRANSPORTATION SYSTEMS TO INCREASE MOBILITY

A series of questions for each advanced system was asked in the survey to determine the likelihood of making more trips by transit alone or by transit, paratransit, or real-time paratransit if a specified information system were available. On-board and kiosk information systems provide various transit information. The on-board information system was described as an electronic bulletin board located on a bus (or light-rail train), and the kiosk information system was described as being similar to an automatic teller machine and located at major bus stops (or light rail stops).

Table 1 shows the percentage of subjects who would make more trips by transit if on-board and kiosk information systems were available. The responses to both the on-board and kiosk information systems are the same. Sixty-four percent of the disabled would make more trips by transit if the systems were available.

Table 1. Stated Increased Use of Transit by Disabled

Information System	*Yes*	*No*
On-board	76 (64%)	42 (36%)
Kiosk	76 (64%)	42 (36%)

In addition to the information provided by the kiosk system, the in-home and personal information systems would provide users with paratransit and real-time paratransit information, and could be accessed through a home computer/TV or from a portable hand-held device.

Table 2 shows that 73 percent of the disabled would make more trips by transit, paratransit or real-time paratransit if an in-home information system were available. And 75 percent would make more trips by transit, paratransit, or real-time paratransit if a personal information system were available.

Table 2. Stated Increased Use of Transit, Paratransit, or Real-time Paratransit by Disabled

Information System	*Yes*	*No*
In-home	86 (73%)	32 (27%)
Personal	88 (75%)	30 (25%)

In general, the disabled state that four information systems would allow them to make more trips by transit, thus enhancing their mobility. In particular, in-home and personal information systems are more attractive to the disabled than the on-board and kiosk information systems. This may be due to the convenience of accessing information prior to travel. With respect to the on-board and kiosk information systems, the user must be either on a bus/rail car or at a bus/rail stop to use the system.

Real-time paratransit was described as a service similar to paratransit except that it allows users to make reservations a minimum of one day in advance. Table 3 shows that if real-time paratransit were available, 77 percent of the disabled would make trips by the real-time paratransit service.

Table 3. Stated Use of Real-time Paratransit by Disabled

Service	*Yes*	*No*
Real-time paratransit	91 (77%)	27 (23%)

Real-time paratransit service information was also provided in the in-home and personal information system; however, fewer of the disabled would make more trips if these two information systems were available than if the real-time paratransit service were available. The transit trip-making attitudes as a result of the in-home and personal information systems could be affected by concerns regarding the understandability of the interfaces used to obtain the service information.

4. MODELING INCREASED USE OF TRANSIT

In order to understand the needs of the disabled population, it is important to identify the factors that influence their travel behavior and perceptions of new technologies. This section describes the statistical analyses done for each of the four information systems and the real-time paratransit service.

4.1. Methodology

Statistical methods were employed to study the likelihood of each system to increase mobility by transit, paratransit or real-time paratransit. The following 15 factors were initially considered in the analysis:

1. disability type (wheelchair, personal assistance, walking aid, other or none)
2. age
3. employment/schooling status
4. education
5. gender
6. car availability (as a driver, passenger in a vehicle, or neither)
7. transit use
8. household size
9. car ownership per household
10. licensed drivers per household
11. household annual income
12. made at least one grocery shopping trip one week prior to the survey
13. made at least one recreational/leisure trip one week prior to the survey
14. made at least one errand trip one week prior to the survey
15. total trips other than work/school trips made one week prior to the survey

A variable pre-selection procedure taking into account main effects and interactions was used to eliminate the insignificant factors prior to modeling the data. Once all the influential factors were determined, a log-linear model analysis was used to examine their association in terms of main factors and interactions. In the cases where interaction terms did not appear, logistic regression models were used to determine the degree of association between the significant variables and perceptions of each system. This allowed for using odds ratios to represent their association strengths. In the cases where interactions were present, the expected count values from the best log-linear model were estimated to represent the strength of association.

The results of association tests in the variable pre-selection procedure indicated that aid type, car availability, education level, and transit use are the significant factors with respect to the increased use of transit as a result of the proposed information systems and real-time paratransit service. A detailed description of the categories for these factors are as follows:

1. Aid type (baseline: no aid)

Wheelchair:	Use wheelchair
Personal assistance:	Do not use wheelchairs but need personal assistance while getting in/out of a vehicle, taking transit, or taking paratransit
Walking aid:	Do not use wheelchairs or require personal assistance, but use walking aids
No aid:	Do not use wheelchairs, require personal assistance, or use walking aids

2. Car availability (baseline: no availability)

Driver:	Car available as a driver
Passenger:	Car available as a passenger
No availability:	No car available as a driver or passenger

3. Education level (baseline: up to high school graduate)

Education: Completed some college or have a higher degree

4. Transit use (baseline: have not used transit in the last year)

Transit: Used transit in the last year

4.2. Model Results of Information Systems

Log-linear and logistic regression models were used to examine the likelihood of increasing mobility by transit alone or by transit, paratransit, and real-time paratransit. The following sections describe the results for each of the proposed advanced traveler information systems.

4.2.1. On-board Information System

As described in the previous section, a variable pre-selection procedure was used to remove insignificant factors that do not influence the stated increased use of transit by the disabled. The results show that stated increased use is significantly influenced by transit use, car availability, and aid type. After applying log-linear modeling techniques, the best model indicates that these three factors affect stated increased use without any interaction. Hence, a logistic regression model is used to represent the association strengths by odds ratios.

The modeling results are shown in Table 4. The odds of transit users making more trips by transit if an on-board system were available is seven times greater than that of non-transit users. The odds of drivers making more trips by transit is lower than that of passengers or those who do not have access to a car. In other words, the odds of those who ride as passengers or those who do not have access to a car to make more trips by transit if the on-board system were available are seven times greater than for those who drive. The odds ratios are not significantly different between passengers and those who do not have access to a car (p-value = 0.30). Those who use wheelchairs or need personal assistance while using a car, transit, or paratransit have less odds of making trips by transit than those who do not. There is no significant difference between those who only need walking aids and those who do not use wheelchairs, walking aids, or require personal assistance (p-value = 0.54).

Table 4. On-board Information System Modeling Results

Analysis of Maximum Likelihood Estimates						
Variable	*DF*	*Parameter Estimate*	*Standard Error*	*Wald Chi-Square*	*Pr > Chi-Square*	*Odds Ratio*
INTERCPT	1	-0.1133	0.7224	0.0246	0.8753	.
TRANSIT	1	1.9035	0.5532	11.8399	0.0006	6.710
(baseline = non-transit user)						
DRIVER	1	-1.9014	0.9410	4.0827	0.0433	0.149
PASSENGER	1	0.5750	0.5511	1.0885	0.2968	1.777
(baseline = no car available)						
WHEELCHAIR	1	-1.5159	0.6057	6.2638	0.0123	0.220
ASSISTANCE	1	-1.1865	0.6405	3.4319	0.0639	0.305
WALKING AID	1	0.7570	1.2437	0.3704	0.5428	2.132
(baseline = no aid)						
Pearson Goodness-of-Fit Statistics=16.4512 with 14 DF (p=0.2866)						

4.2.2. Kiosk Information System

The results of the variable pre-selection procedure indicated that the stated increased use of transit is influenced by current transit use, aid type, and car availability. The final log-linear model demonstrates that three interactions exist. Given kiosk system perception (K), transit use (T), aid type (A), and car availability (C), the final log-linear model can be statistically illustrated by: [KAC][KAT][KCT]. The perception of the kiosk information system is of interest as the response variable, therefore, the interpretations of the three-way interactions are as follows:

[KAC]: The effect of aid type on kiosk perception is influenced by car availability (or, the effect of car availability on kiosk perception is influenced by aid type).

[KAT]: The effect of aid type on kiosk perception is influenced by transit use (or, the effect of transit use on kiosk perception is influenced by aid type).

[KCT]: The effect of car availability on kiosk perception is influenced by transit use (or, the effect of transit use on kiosk perception is influenced by car availability).

Based on the model, the estimated cell counts are shown in Table 5. In general, if a kiosk information system were available, transit users would be more likely to make more trips by transit than non-transit users. Those who use wheelchairs would be less likely to make more trips by transit than those who do not use wheelchairs. Car availability interacts with aid type, transit use, and with kiosk perception. Since a large number of cell counts are less than five, a larger sample size is required to verify the effects of the three variables. However, it is apparent that many non-wheelchair users who are passengers or who do not have access to a car have positive attitudes about transit use as a result of the kiosk information system.

Table 5. Estimated Frequencies for Kiosk Information Systems

Aid Type	*Car Availability*	*Transit User*	*Make More Trips by Transit?* No	Yes	Total
Wheelchair	Driver	Yes	1.1	1.9 (63%)	3
		No	3.9	2.1 (35%)	6
	Passenger	Yes	1.0	3.0 (75%)	4
		No	3.0	1.0 (25%)	4
	No	Yes	5.9	4.1 (41%)	10
		No	4.1	0.9 (18%)	5
Personal assistance, Walking aid, or no aid	Driver	Yes	0.9	1.1 (55%)	2
		No	3.1	0.9 (23%)	4
	Passenger	Yes	5.0	40.0 (89%)	45
		No	7.0	5.0 (42%)	12
	No	Yes	5.1	14.9 (75%)	20
		No	1.9	1.1 (37%)	3

Note: [dark shading] : percent >= 70%; [light shading] : 50 % <= percent < 70%

4.2.3. In-home Information System

In addition to transit information, the in-home information system provides paratransit and real-time paratransit information. The significant factors affecting the likelihood of increasing mobility by taking transit, paratransit, or real-time paratransit if an in-home information system were available are car availability and education level. The results of the logistic regression model are shown in Table 6.

Table 6. Modeling Results for In-home Information Systems

Analysis of Maximum Likelihood Estimates						
Variable	*DF*	*Parameter Estimate*	*Standard Error*	*Wald Chi-Square*	*Pr > Chi-Square*	*Odds Ratio*
INTERCPT	1	1.3034	0.4262	9.3542	0.0022	.
DRIVER	1	-3.5266	1.1574	9.2848	0.0023	0.029
PASSENGER	1	-0.3986	0.5174	0.5935	0.4411	0.671
(baseline = no car available)						
EDUCATION	1	2.2630	1.0667	4.5004	0.0339	9.612
(baseline = high school degree or less)						
Pearson Goodness-of-Fit Statistics=1.4151 with 2 DF (p=0.4829)						

The odds of drivers making more trips by transit, paratransit, or real-time paratransit is lower than that for passengers in cars or those who do not have access to a car (34 times less likely). There is no significant difference between passengers and those who do not have access to a car (p-value = 0.44). Those who completed college or who have a higher degree have about 10 times greater odds of making more trips by transit, paratransit, or real-time paratransit than those who have a high school degree or less.

4.2.4. Personal Information System

Similar to the model results of the in-home information system, the significant factors influencing the use of transit as a result of the personal information system include car availability and education level. The results of the logistic regression model are shown in Table 7 below.

Table 7. Modeling Results for Personal Information Systems

Analysis of Maximum Likelihood Estimates						
		Parameter	*Standard*	*Wald*	*Pr >*	*Odds*
Variable	*DF*	*Estimate*	*Error*	*Chi-Square*	*Chi-Square*	*Ratio*
INTERCPT	1	0.9646	0.3915	6.0722	0.0137	.
DRIVER	1	-2.7971	1.1389	6.0324	0.0140	0.061
PASSENGER	1	0.1122	0.4977	0.0509	0.8216	1.119
(baseline = no car available)						
EDUCATION	1	2.5730	1.1027	5.4443	0.0196	13.106
(baseline = high school degree or less)						
Pearson Goodness-of-Fit Statistics=2.9120 with 2 DF (p=0.2332)						

The odds of drivers making more trips by transit, paratransit, or real-time paratransit is lower than that for passengers and those who do not have access to a car (16 percent less likely); however, there is no significant difference between passengers and those who do not have access to a car (p-value = 0.82). Those who completed college or who have a higher degree have approximately 13 times greater odds of making more trips by transit, paratransit, or real-time paratransit than those who do not. There is no significant difference among those who need personal assistance, a walking aid, and those who need no aid.

4.3. Model Results for Real-time Paratransit

The results of the variable pre-selection process show that the significant factors are car availability and aid type. Logistic regression was used to examine the likelihood of increasing transit use if a real-time paratransit service were available. The results are shown in Table 8 below.

Table 8. Modeling Results for Real-time Paratransit Services

Analysis of Maximum Likelihood Estimates						
		Parameter	*Standard*	*Wald*	*Pr >*	*Odds*
Variable	*DF*	*Estimate*	*Error*	*Chi-Square*	*Chi-Square*	*Ratio*
INTERCPT	1	0.8646	0.4871	3.1513	0.0759	.
DRIVER	1	-2.3838	0.8791	7.3534	0.0067	0.092
PASSENGER	1	0.3869	0.5585	0.4799	0.4884	1.472
(baseline = no car available)						
WHEELCHAIR	1	2.1791	0.8516	6.5481	0.0105	8.838
ASSISTANCE	1	-0.0740	0.5915	0.0156	0.9005	0.929
WALKING AID	1	12.5007	343.7	0.0013	0.9710	999.000
(baseline = no aid)						
Pearson Goodness-of-Fit Statistics=3.4219 with 5 DF (p=0.6352)						

The odds of drivers making more trips by real-time paratransit if available is lower than for passengers and those who do not have access to a car. There is no significant difference between those who ride as passengers in cars and those who do not have access to a car (p-value = 0.49). Those who use wheelchairs have higher odds of making more trips by real-time paratransit than those who do not.

5. SUMMARY OF MODEL RESULTS

Table 9 summarizes the factors affecting the increased use of transit by disabled travelers as a result of an on-board system, kiosk system, in-home, and personal system as well as the use of real-time paratransit if it was available.

Table 9. Influential Factors in Increased Transit Use for the Proposed Systems

Factors	On-board	Kiosk	In-home	Personal	RT Paratransit
Car availability	x	x	x	x	x
Aid type	x	x			x
Transit use	x	x			
Education			x	x	
Car availability×Aid type		x			
Car availability×Transit use		x			
Aid type×Transit use		x			

Note: "x" indicates a significant factor

The findings from these models are as follows:

1. Car availability is a significant factor for all five models. Compared with drivers, those who ride as passengers in cars and those who do not have access to a car have greater odds of increasing trips by transit alone or by transit, paratransit, or real-time paratransit, if an advanced system were available. This indicates that the proposed advanced information systems and transportation service are instrumental in enhancing the mobility of those who do not drive.

2. Non-wheelchair users would be more likely to use transit than wheelchair users if an on-board or kiosk system were available. In regards to transportation services, wheelchair users, in particular, have positive attitudes about using real-time paratransit.

3. Transit users would be more likely to increase trips by transit than non-transit users if an on-board or kiosk information system were available. These systems should be considered to enhance the mobility of transit users since the majority of the disabled are transit users.

4. Level of education is a significant factor in the stated use transit as a results of the in-home and personal information systems. Those who completed college or have a higher degree have greater odds of using the in-home and personal information systems than those who do not. One possible reason for this is that those with more education feel more comfortable using a computer, TV, or personal interface (i.e., personal digital assistant system) to obtain transit or paratransit information. It is therefore essential to design user friendly systems and to demonstrate that these information systems are easy to use.

Since aid type was a significant factor in the stated use of transit as a result of the on-board and kiosk information systems and also the use of real-time paratransit, the relationship between system use and aid type was examined by chi-square tests or Fisher's exact test. The result is shown in Table 10.

The results indicates that wheelchair users had a more positive attitude about using transit as a result of the in-home information system, personal information system, and the real-time paratransit service than the on-board and kiosk information systems (p-value = 0.001). There were no other significant differences in the use of the four information systems or the real-time paratransit service for the subjects who require personal assistance, walking aids, or no aid (p-value = 0.7, 1.0, 0.6, respectively). It appears then that the in-home and personal systems, along with the real-time paratransit service, can benefit wheelchair users by enhancing their mobility.

Table 10. Use of Information Systems and Real-time Paratransit by Aid Type

Aid Type	*N*	*On-board*	*Kiosk*	*In-home*	*Personal*	*Real-time Paratransit*	*P-value*
Wheelchair	32	**11 (34%)**	**13 (41%)**	**23 (72%)**	**25 (78%)**	**28 (88%)**	**0.001**
Personal assistance	21	12 (57%)	13 (62%)	16 (76%)	14 (67%)	15 (71%)	0.7
Walking aid	7	6 (86%)	6 (86%)	7 (100%)	6 (86%)	7 (100%)	1.0
No-aid	58	47 (81%)	44 (76%)	40 (69%)	43 (74%)	41 (71%)	0.6

6. CONCLUSIONS AND SUGGESTIONS

The results of the survey show that disabled persons who do not use wheelchairs find it difficult to walk up or down a flight of stairs, stand for more than 15 minutes at a time, stand outside in extreme weather conditions, and reach for objects higher than six feet. Wheelchair users have the most trouble traveling three blocks without resting, picking up objects from the floor, carrying a bag of groceries, and reaching for objects higher than six feet. With this in mind, advanced transportation services should be designed keeping in mind these difficult situations. For example, the waiting time for transit and paratransit services should not exceed 15 minutes, and bus shelters should be built when feasible.

In general, the on-board (64%), kiosk (64%), in-home (73%), and personal (75%) information systems could enhance the mobility of disabled persons. However, a difference of approximately ten percent indicates that the in-home and personal systems are more attractive to the disabled, as these two information systems are more accessible and allow users to obtain transit, paratransit, and real-time paratransit information prior to travel.

Real-time paratransit shows a great potential to increase the mobility of the disabled, especially for wheelchair users. Although real-time paratransit was included in the in-home and personal information systems, respondents showed somewhat greater preference towards the service itself (77%) than the use of the information systems. This generates concern over the types of interfaces proposed and should be of particular focus in future research.

The results of the logistic regression and log-linear models show that perceptions of the on-board and kiosk systems are influenced by car availability, aid type, and transit use. In particular, these systems are favored by those who do not drive, do not use wheelchairs, or use transit.

Perceptions of the in-home and personal information systems are influenced by car availability and level of education. As with the on-board and kiosk systems, these are favored by those who do not drive. In addition, those who have at least a college degree stated that they would make more trips than those who do not have a college degree if these two systems were available. This may be because those with more education feel more comfortable using a computer, TV, or personal device to obtain transportation information.

The influential factors on the stated use of real-time paratransit include car availability and aid type. From the results, non-drivers and wheelchair users are expected to benefit the most from this service.

Based on these results it appears that in-home and personal information systems along with real-time paratransit could increase the mobility of the disabled population.

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