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16. Abstract

There is a general assumption that the elderly are unfamiliar or uncomfortable with technology – that has been the premise for most studies researching the benefits of Intelligent Transportation Systems (ITS) for elderly drivers. While the preconceived notions about technology and the elderly may ring true for older generations of the elderly, a marked change is to be expected for current and future elderly cohorts, as these groups are more likely to have grown up with the technology, or watched and participated in its development. In addition, currently available technologies such as in-vehicle systems are still considered luxury add-ons, and have been purchased by the elderly. Thus the question arises how ITS can enhance elderly persons' mobility given that the society is generally aging, and that society is becoming more accustomed to new technologies. However, the challenge of predicting benefits for an aging cohort that is not yet elderly is two-fold, first the underlying assumption that behavior patterns will not change may have serious implications and secondly, the technologies themselves are still developing, and as such, the effects, in many cases, are yet to be observed. A dynamic assessment model is then needed to evaluate transportation systems for the society at large and the elderly in particular.

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Intelligent Transportation Systems to Improve Elderly Persons' Mobility and Decision Making within Departure Time Choice Framework

by

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Research Report SWUTC/03/167531-1

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EXECUTIVE SUMMARY

Over the past few years, the aging of the nation has received much attention across all fields of study, and in transportation it is a growing area of research. Indeed, discussions about transportation for an aging society began about a decade and a half ago when the Transportation Research Board initiated a study to review design and operational features of transportation systems as relates to older users. Today, there is plenty of ongoing research on the use and implementation of Intelligent Transportation Systems (ITS) technologies to improve transport service provision and efficiency. However, there is somewhat limited research that studies the effects of the interaction of an aging *and* technologically advancing society. The elderly user needs special consideration in the design of systems that are intended to aid the use of transport facilities, particularly because the aging process imposes restrictions on otherwise healthy individuals. Whereas the elderly driver is seen as a potential risk to the highway system and its users, particularly with advancing technologies and intelligent transportation systems, transportation planners believe that the new technologies are likely to restore the elderly driver's self confidence and increase overall system safety and efficiency. It has been argued that the elderly are less technologically adept than younger cohorts. While it may be true that differences do exist between elderly and younger persons, the apparent gap in technological awareness is likely to be reduced for the future elderly.

As far as the elderly are concerned, Advanced Traveler Information Systems (ATIS) will prove more useful both for the urban/suburban and rural elderly. Urban dwellers may need real time traffic information while rural dwellers may be more interested in real time weather conditions and the availability of expedient Emergency Medical Response (EMR) services. Thus the question is not 'whether ATIS will improve mobility' but 'how much' of a factor it will be in the decision making process of an elderly traveler. How can these benefits be quantified, and what impact will technology have on the trip making behavior of a 'technologically savvy' elderly cohort? To answer the question on how ITS can enhance elderly persons' mobility given that the society is generally aging, and that society is becoming more attuned to technology provides a double challenge. To begin with, predicting benefits for an aging cohort who is not yet elderly is twofold as it entails an underlying assumption that patterns of behavior will not change. Furthermore, the technologies themselves are still developing, and as such, the effects, in many cases, are yet to be observed and fully understood. A dynamic assessment process is then needed to evaluate the benefits of intelligent transportation systems for the society at large, and the elderly in particular.

The availability of ATIS may impact the choices travelers make along several dimensions such as choice of mode, route or departure time. This study looks at departure time to analyze the temporal preferences of elderly persons. This is critical since many of the elderly persons will perhaps no longer be working and whose travel behavior then, is expected to differ from the rest of the population.

The results of the preliminary study confirm that elderly road users exhibit different travel patterns from the general population. That elderly persons prefer the earlier part of the day, particularly on weekdays has implications for the transportation system – for instance with the projected increases in elderly persons and subsequently more retired/non-working persons, there may be noted increases of roadway usage during the day. From a systems standpoint, this could be looked at both positively and negatively; positively in the sense that increased usage during off-peak hours may tend to minimize the underutilization of transportation infrastructure. On the other hand, increased usage may require additional resources, for instance available emergency response units, or result in non-renewable resource abuse due to increased vehicular emissions. Understanding the travel needs of an increasing population segment such as the elderly will be useful in tailoring programs that have been traditionally geared towards reducing vehicular demand. The availability of suitable transport alternatives, such as transit at the times they are most needed, may serve as an incentive to switch modes from the predominant privately owned vehicle.

This study serves as a preliminary analysis and more research is needed to augment these preliminary findings and evaluate the impact of ITS on the decision process of elderly travelers. For instance an interactive process may be developed to assess the switching propensities due to real time traffic or weather information. Elderly drivers reported valuing information about weather conditions while younger drivers did not tend to value this information as much. The potential of ATIS systems in this regard may assist drivers who are already away from home in making decisions about their return trip. The initial individual decision of whether or not to invest in ATIS, in-vehicle navigation systems (IVNS) or in-vehicle safety systems (IVSS) depends upon the subjective evaluation of various packages against individual criteria such as: costs, the type of information provided, detail level of information, ease of use of system, legibility of in-vehicle display units, and other more subjectively perceived benefits such as increased confidence. The day-to-day travel decision is a more dynamic process in that decisions are made as the information is received. For pre-trip and en-route information, drivers may alter routes, or switch destinations. In the case of pre-trip information, departure time may be modified or the trip may be cancelled altogether, whereas en-route information may cause drivers to abort the trip. At the agency level, decisions to be made include the allocation of resources, for example, emergency response units or the dissemination of the information itself.

ABSTRACT

There is a general assumption that the elderly are unfamiliar or uncomfortable with technology – that has been the premise for most studies researching the benefits of Intelligent Transportation Systems (ITS) for elderly drivers. While the preconceived notions about technology and the elderly may ring true for older generations of the elderly, a marked change is to be expected for current and future elderly cohorts, as these groups are more likely to have grown up with the technology, or watched and participated in its development. In addition, currently available technologies such as in-vehicle systems are still considered luxury add-ons, and have been purchased by the elderly. Thus the question arises how ITS can enhance elderly persons' mobility given that the society is generally aging, and that society is becoming more accustomed to new technologies. However, the challenge of predicting benefits for an aging cohort that is not yet elderly is two-fold, first the underlying assumption that behavior patterns will not change may have serious implications and secondly, the technologies themselves are still developing, and as such, the effects, in many cases, are yet to be observed. A dynamic assessment model is then needed to evaluate transportation systems for the society at large and the elderly in particular.

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CHAPTER 1. INTRODUCTION

There is much talk about the changing face of the U.S. population distribution as baby boomers grow older and approach retirement age. In fact, discussions about transportation for an aging society began about a decade and a half ago when the Transportation Research Board initiated a study to review design and operational features of transportation systems as relates to older users (1). At that time technology issues were hardly on the agenda. Today, there is plenty of ongoing research on the use and implementation of Intelligent Transportation Systems (ITS) technologies to improve transport service provision and efficiency. However, there is somewhat limited research that focuses specifically on the impacts of new technologies on elderly drivers as it is quite challenging to capture within a single study, the effects of the interaction of an aging *and* technologically advancing society. Implicit in these studies and deployment strategies is the assumption that travel patterns in the future will mirror those we see today – with congested peak-hour travel, where the majority of trips are commute trips. With an aging population, and for the first time, a larger proportion of elderly persons; the impact of these developments on transportation needs to be analyzed and basic assumptions revisited.

As the distribution of the U.S. population distribution approaches the shape of an inverted pyramid there is a need to re-assess typical transportation assumptions; for example, reaction time, a parameter which is based on population averages and is used in traffic engineering calculations may have substantial safety implications when a larger proportion of the population does not subscribe to the typically assumed characteristics. What implications does an inverted pyramid have for reaction time, travel time, implied or perceived safety? In terms of *Freeway Management Systems*, and the implementation of ramp-metering, what are the implications for the elderly? In response to general concern for elderly road users, the Federal Highway Administration (FHWA) has recently published highway design guidelines that will incorporate older driver needs such as increased lettering size for highway guide signs (2). As the population ages, are there provisions for adequate health or emergency related services? And how can ITS be utilized to ensure efficient incident management and minimize emergency response times? Over the past decade, Texas and the rest of the U.S. have witnessed the emergence of Traffic Management Centers, whose aim is to streamline the response mechanisms for transport related incidents. Along with the provision of real time traffic and traveler information systems, transport networks are better prepared to handle adverse conditions and are geared towards safety of the general population.

The elderly user needs special consideration in the design of systems that are intended to aid the utilization and enjoyment of transport facilities, particularly since the aging process imposes restrictions even on otherwise healthy individuals. There are various areas of interest that may be studied in trying to substantiate today's investments for tomorrow's population, for example the technicalities involved in the design of in-vehicle systems, or the safety implications of system-wide deployments. Whereas, the older driver is seen as a potential risk to the highway system and its users, particularly with advancing technologies and intelligent transportation systems, ITS technologies may in fact restore elderly road users' self-confidence and enhance their experience thus increasing overall system safety and efficiency. At the same time, besides the compensatory techniques such as are employed in vehicles, or rehabilitative measures that may be offered by medical advances, elderly drivers themselves do give up driving altogether, or stop using public transport, once they deem it no longer feasible. The question then for planners is whether tomorrow's elderly driver will exhibit the same characteristics as yesterday's driver – it may be found that the elderly driver is in fact more well prepared to handle the driving task, even under duress, than the younger driver. While it may be apparently easier to pinpoint the benefits of ITS for the elderly road user, a somewhat more difficult, yet necessary question is that for the case of public transport users and pedestrians. While all of transportation planning is intertwined with land use patterns, the latter two users are heavily dependent on conscious and integrated models of development for transport facilities. Finally, of particular interest to transport planners and traffic engineers is the temporal distribution of trips, both work and non-work, as these have environmental and operational impacts on transportation systems.

1.1. AGING DRIVERS

The effects of aging are numerous and have been well documented elsewhere (1, 3-5), but a brief description of some of the more critical effects on mobility and driving are highlighted here below. The elderly undergo physiological changes as they age, which affect their sensory and cognitive abilities (1, 6, 7). These changes have an impact on the driving task as response times, glance times, information processing times (both audio and visual reception) increase due to reduced acuity. In addition older persons may also undergo ambulatory changes that inhibit driving, and at the extreme end prohibiting driving altogether (6). For their part, older drivers are likely to adjust attitudes and behaviors in response to their own changing capabilities. Driver and road user safety is of paramount concern, and as such has been the focus of many studies involving the elderly. Due to reduced capabilities such as mental alertness and slower reaction times, the older driver has been viewed as an “at-risk” driver. Older drivers are believed to present a risk not only to themselves but also to other road users. However, what must not go unmentioned is the changing nature of the elderly population. Past populations, have perhaps, been exposed less to driving than, say, baby boomers. Indeed statistics indicate that elderly drivers have been traveling more in the past few decades (8-10). Along with advances in medical as well as and in-vehicle technologies, the driving task for the future elderly cohort may provide altogether different challenges. Furthermore, as more people age-in-place, urban planners will need to make necessary adjustments to cater to the needs of the growing elderly population in their cities.

Sensory

In general one’s visual and auditory acuity diminishes as one ages. This poses some problems for the driving task as driving competence is heavily dependent on the ability to adapt to the dynamic driving environment – moving objects around you, changing traffic signals, warning/advisory signs such as a horn etc. The older driver is susceptible to reduced vision due to hardening, yellowing and loss of transparency. This results in reduced peripheral vision and ‘Useful Field of View’ which may cause drivers to increase their following distance or drive slower.

Cognitive

The cognitive abilities associated with driving involve the absorption of incoming information and the interpretation of such information to enable decision-making. Driver attention (or in-attention) is a commonly cited cause for accidents. Driver attention is divided into three categories, selective, divided and sustained (11). *Selective* attention relates to the ability to shift and focus on different stimuli. *Divided* attention relates to the ability to perform two or more tasks simultaneously – driving itself is by nature a multi-task process. *Sustained* attention relates to the ability to detect infrequent changes in the driving environ, for example a deer or child in front of the car. A reduction in mental alertness may limit elderly drivers’ capabilities, as with visual problems, drivers may again choose to drive slower or increase their following distance. There are also other implications, for instance, if traveling long distances, older drivers may not respond quickly enough to avoid approaching hazards.

Mobility

Due to improved healthcare and healthier lifestyles, life expectancy has increased. In some cases this leads to dependency on the part of elderly persons who can no longer drive as they more and more rely on others for transportation to and from their destinations. The lack of mobility and associated dependency may have secondary effects for instance isolation or depression (12). The mobility of the elderly is of concern to transport agencies. Past studies have primarily focused on providing “alternative” means of transport. The future generation of elderly drivers will undoubtedly be somewhat different from the elderly cohort of yesteryear, the subject of many studies. Following the auto-mobilization of the US in general, it is no wonder that the baby-boomer cohort has grown up with unprecedented access to a personal vehicle. Along with the growth of the highway system came the transformation of land use patterns, with densification away from urban areas. The scenario further compounds an already dire public transportation situation, in that mass transit is for the most part limited to urban areas, and is more often the ‘other’ alternative to the personal automobile for the elderly driver. ITS technologies, with capabilities of providing real time information, and the exponential growth of the electronic information industry, offer alternative means of transport a powerful marketing tool – and offers potential users access to information for better decision-making.

1.2. CORRECTIVE MEASURES

In response to the effects of ageing, several remedial measures have been developed and implemented. Among some corrective measures that have been adopted are:

Medical

Deficiencies in sensory capacities can be remedied by medical/surgical procedures, or by using aids developed in the medical field e.g. hearing aids or laser eye surgery to improve vision. Other medical measures may relate to the personal mobility of a person.

Physical Environment

Some improvements to mobility may be achieved due to enhancement of the physical environment – for instance the use of a personal walker or wheelchair. Over the past few decades, particularly after the passing of the Americans with Disabilities Act (1990) there has been much attention to the provision of accessible services. While the act itself was geared towards increasing quality of life for handicapped persons, much of the work in that area also directly affects elderly persons – for one, the aging process itself may render them physically challenged, secondly, due to their enhanced vulnerability, they may experience excessive or repeated injuries such as falls or broken hips.

ITS

ITS technologies such as in-vehicle systems provide some relief in that expected driver contribution to the driving task may be reduced. For the elderly driver this is particularly helpful in light of reduced sensory and cognitive capacities. These systems include: advanced traveler information systems (ATIS), advanced travel management systems (ATMS), advanced vehicle safety systems (AVSS), advanced public transportation systems (APTS), in-vehicle route and navigation systems (IVNS), in-vehicle safety systems (IVSS) collision avoidance/warning systems (CAS/CWS), vision enhancement systems (VES), travel and traffic information systems, autonomous intelligent cruise control among others. These systems offer information, navigational aids, advisory and warning capabilities which make traveling on highways or on public transportation (transit) more enjoyable and increase overall systems safety and efficiency.

Legal

Another compensatory measure is the self-imposed restriction adopted by the driver her/himself. In surveys, elderly persons have reported giving up driving when they no longer felt comfortable. Intervention and the revoking of licenses in some instances also keeps "at-risk" drivers off the road.

1.3. SUMMARY

Due to recent medical advances, improved healthcare and healthier lifestyles, people are living longer in the U.S. and much of the developed world. Across many fields of research, the ageing population is receiving much attention as an "older" population has several implications. The changing demographics, an increase in elderly proportions, presumably will place different demands on current infrastructure and service systems. For instance, there may be increased demand for retirement benefits or financial planning services; increased demand for assisted living facilities or healthcare; a reduction in workforce and increased need for workforce training and replacement; or an increased demand for recreational activities and destination options, among others. The effects of an ageing population are numerous, but the intent of this study is to focus on the changing nature of demand for transportation in an ageing society. Understanding the factors that impact the elderly traveler's decision process is crucial to the provision of efficient and safe transportation systems. The importance of adequate transportation systems to the quality of life of all persons cannot be understated as transport is a fundamental basis to any thriving economy and critical to enhanced accessibility and mobility options. Furthermore, a focused research effort is required for senior citizens as the ageing process imposes physiological changes on the elderly, which may diminish their sensory and cognitive capabilities, thus limiting their transport options in that driving requires mental, visual and audio acuity while alternative transport such as transit or walking, require physical fitness. With the projected growth of the elderly population, the impacts on transportation systems need to be assessed in order to prepare to serve well, an increasing segment of the population. This first chapter has laid the background for the rest of the work in this study – while compensatory measures range from medical or surgical procedures to changes in the physical/built environment, new technologies promise efficient transportation solutions. ITS technologies aim to increase overall system safety and efficiency, while at the same time enhancing mobility. The importance of changing demographics to future transportation demand management and operations, and the impact that ITS technologies will have in shaping demand are discussed in subsequent chapters. The following chapter gives an overview of the relevant literature.

CHAPTER 2. ELDERLY AND ITS IN TEXAS

The 'elderly' population is loosely defined and can be grouped in several ways, but nevertheless the population of older persons is certain to increase over the next few years. The Texas Department on Aging reports that Texas has the fourth largest elderly population in the nation (10%) and that the poverty rate among the elderly is higher than the national average. It is expected that by 2025, approximately 16% of Texas residents will be over 65. Females form the majority of the elderly population, with 68 males for every 100 females (13). These facts have serious implications for Texas. For one, mobility of low-income individuals may be compromised since many may not have access to a personal vehicle – to that end, transport alternatives would need to be provided. In addition to the aging of the population, there are more women drivers now than in previous years. Furthermore, women tend to outlive men and with the changing social structure of U.S. households, more elderly women are expected to drive in the future. What then might the implications be for transportation systems that have generally been designed for the healthy young male?

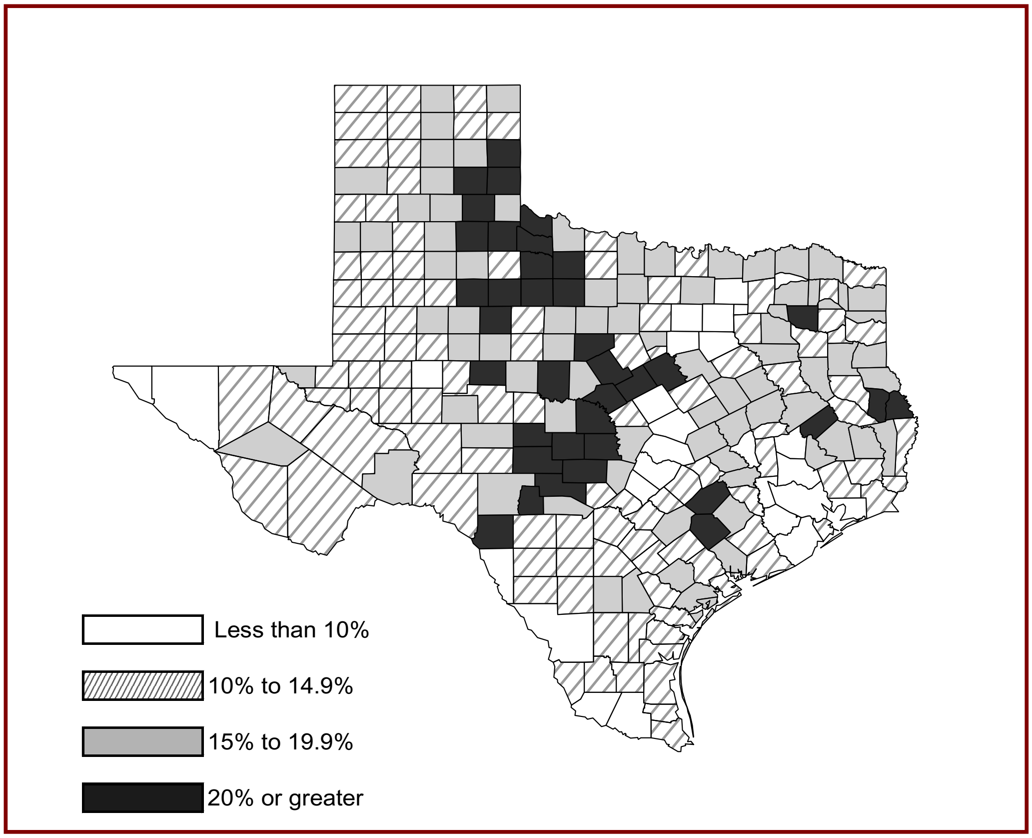
2.1. DEMOGRAPHIC CHARACTERISTICS OF THE ELDERLY IN TEXAS

In Texas, the majority of the elderly live in metropolitan areas – the same is true for other segments of the population. However, the elderly population has a smaller share living in metropolitan areas and larger representation in rural areas. This is important in the allocation of resources to meet constituents' needs. On the other hand, if the aging-in-place trends are to continue, then it can be expected that there will be more elderly living in urban and suburban areas in the future.

The Texas State Data Center reports that the elderly grew at a faster rate than the general population, at a rate of 25.5% over the last decade compared to 19.4%. In addition, about 25% of elderly Texans are either Hispanic or Black, and accounted for about 27% of the growth. The elderly comprised nearly 12 percent of the White population, 7.8 percent of the Black population, and 5.3 percent of the Hispanic population (14).

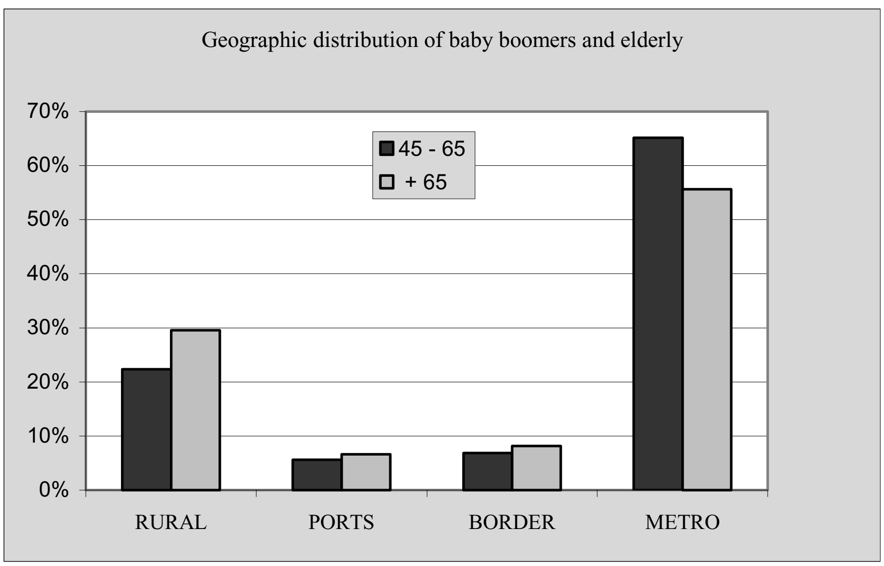
A survey of elderly travelers in California, (12) found that the majority of elderly live in suburban areas and as such, private automobiles were the most convenient form of transportation. It also found that 70% of elderly were selective about the time of day they drive due to concerns about roadway conditions. 56% of those surveyed did not view public transport as a viable choice. The report also cites a Volpe study that found that more than 75% of elderly persons live in suburban areas, 82% of whom lived in detached, single family homes. This has implications for ridesharing or transit use as transit works best in densely populated areas with high volume corridors and offers a CBD (central business district) as primary destination. This may not coincide with elderly persons' needs. In addition, more service is offered during peak hours – with less frequent service during the times that elderly want to travel.

Figure 1: Geographic Distribution of Elderly in Texas



That the majority of elderly persons is located in rural areas generates concern in that; first there are few alternatives to the automobile as a means of transport and secondly, fatal crashes have been reported to be higher in rural areas (15). This latter concern may be attributed to the increase in emergency response times, which could be related to the communication systems or lack thereof in rural areas. The communication breakdown can be fixed by the introduction of ITS systems in rural areas with monitoring devices such as video detection with links to an emergency response system – this should benefit all rural inhabitants. The elderly are particularly sensitive to the lack of alternative means of transport as they more likely than not have fostered dependence on a personal vehicle to get around. As their driving capabilities may be challenged with age, few options exist for them. With the proliferation of information technologies across all fields, this particular problem may be a thing of the past. ITS technologies hold promise of improving driver capabilities, especially for "at-risk" drivers. The development of in-vehicle systems such as collision avoidance, object detection, warning/alarm systems, fatigue detection will aid all users. For the older driver, developments in transport as well as medical advancements are likely to increase the percentage of older drivers still able to drive.

Figure 2: Distribution of Elderly within Texas Districts



This chart shows the distribution of the baby boomers and the elderly in the four regions as identified by Ory (16), in his report of ITS deployments in Texas. As can be seen, currently elderly persons are more represented in rural areas than younger cohorts. Alternatively, in the future, we can expect larger proportions of elderly in metropolitan areas if the "aging-in-place' trends are to continue.

2.2. ITS DEPLOYMENT IN TEXAS

A summary of ITS deployments for the entire state of Texas was provided by Ory in his report (16). The Texas Department of Transportation (TxDOT) has freeway traffic management systems in operation within 6 major urban areas in Texas: Houston, Dallas, San Antonio, Fort Worth, El Paso, and Austin, controlled by an operational Transportation Management Center (TMC).

The freeway systems include Closed Circuit Television (CCTV), Dynamic Message Signs (DMS), and vehicle detectors. Some also contain lane control signals, ramp meters, electronic vehicle identification tags and readers, traveler information systems, and High Occupancy Vehicle (HOV) Lane systems. The freeway systems all perform, at a minimum, incident detection and management, traveler information dissemination, data collection, and area-wide control and surveillance.

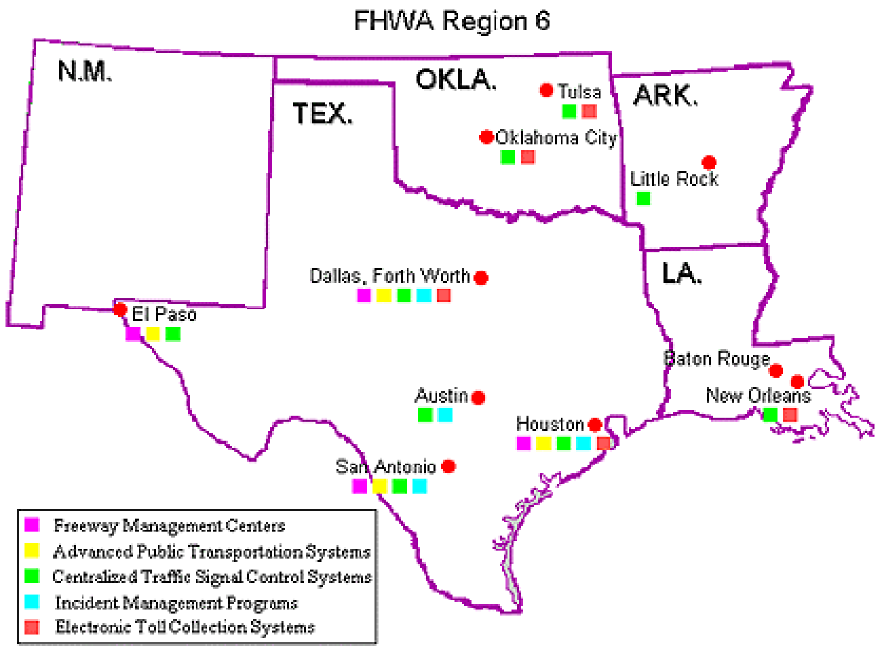
The U.S. Department of Transportation (US-DOT) tracks ITS deployments nationwide and has received survey results from five metropolitan areas in Texas. Brief descriptions from these sources are highlighted.

In Houston, TranStar operates a comprehensive traffic management center, which monitors traffic conditions to enable speedy responses to emergencies and incidents. In addition, METRO operates the largest HOV network in the country, covering 105 miles of barrier-separated lanes.

Transguide in SanAntonio provides real-time, multi-modal traveler information was provided to the public through in-vehicle route guidance systems, kiosks, and the Internet.

DART uses Global Positioning Systems (GPS) and Automatic Vehicle Location (AVL) technology to track their 1,280 buses. Texas Turnpike Authority in Dallas maintains an electronic toll collection system on the North Dallas Tollway

Figure 3: ITS Deployments in Texas[1]



[1] Source: www.its.dot.gov/staterpt/tx.htm

CHAPTER 3. LITERATURE REVIEW

The literature reviewed includes general literature about the effects of aging on personal mobility and on the provision of transportation services. Other studies reported on tests conducted on the operational merits of specific ITS packages, with some addressing elderly issues in particular. Many studies are based on the premise that older persons are technologically impaired or inferior. However it may be that the next-generation of elderly will not exhibit such 'fear' or 'inadequacies' when it comes to technology and the use of ITS as a transport enabler.

3.1. AGING PROCESS

Due to improved health facilities, life expectancy has increased and it is suggested that people live longer than they can "safely operate an automobile" (17). Thus the increased life expectancy creates a certain dependence for elderly persons who can no longer drive as they more and more rely on others for transportation to and from their destinations. In some cases, some elderly persons will have no one to give them a ride, which for most persons is an inevitable eventuality as age increases. Burkhardt found that elderly persons over 75 are most likely to experience declines in driving (17). This has important implications for the social integration of the elderly – reduced driving capabilities reduces mobility, as defined by number of trips, and increases the reliance on others – in effect reducing one's independence – which may have psychological impacts and as has been suggested, could also lead to social isolation (12, 18), and perhaps even depression (3, 4, 19).

Transport is commonly viewed as a facilitator, thus the lack of transport may render elderly persons homebound when perhaps they would rather be elsewhere. Indeed, as Burkhardt asserts, "in terms of transportation, one of the strongest implications of the aging process is a loss of personal independence" (17). As with other studies, he also points out that many elderly are likely to age in place, and that furthermore, baby boomers are typically found in suburban areas – thus place "different demands on transportation and service systems" (17, 19). Burkhardt acknowledges that, "projecting the amount of driving by elderly persons is fraught with uncertainty". However, he does consent that the expectation that seniors will drive more is probably valid. Burkhardt identifies the shortcomings of public transportation as an option for elderly, such as "select access to origins and destinations, limited service (frequency issues), perceived out of pocket cost, other LOS [Level of Service] variables related to auto, that are also preferred by general population such as flexibility". In addition automobile use offers users a sense of autonomy since departure times, ride comfort such AC levels, radio, can be determined independently.

Many studies focus on the differences between older and younger drivers, for instance, , a study by the Federal Highway Administration (FHWA) reports that elderly drivers have been found to drive slower, exhibit larger variability in lateral [lane] placement, have longer reaction times to instruments, are more likely to be in another lane after a turn, and are more likely to make navigational errors than younger drivers (4). This may be due to a reduction in sight capabilities – "Vision can be affected in many ways as age increases… As the eye ages, the lens begin to harden, lose transparency and yellow. Hardening of the lens reduces the ability to accommodate reducing near field visual acuity. Most studies however, show a low correlation between static visual acuity and accident rates. Yet tests of static visual acuity are currently the most common method of testing vision abilities for licensure". Mollenhaer et al point out a possible shortcoming in testing methods that are geared to provide "intervention" for "at-risk" drivers (11). They also point out that the irreversible negative trend that begins in the mid twenties creates a need for double the amount of illumination required to maintain a given level of visual performance for every 13 years increase in age. The less light that is available, the greater the loss in visual acuity, resulting in slower reaction times. The loss of transparency in the eye causes discomfort and disability when facing glare from either sunlight or oncoming vehicles. ITS technologies may offer various solutions to the diminished visual capabilities of elderly persons, for example, the installation of Visual Enhancement Systems on windshields.

A study reports that approximately 25-50% of crashes is due to inattention (11) and that studies correlated poor *selective* attention performance to higher accident rates in older persons, but that there was little evidence to support the hypothesis that poor *divided* attention capabilities result in increased accidents. In addition, the study reports that there has been no research to support the hypothesis that *sustained* attention reduces with age. However ITS technologies included under collision avoidance and warning systems may help alleviate problems due to inattention, for elderly drivers and all other population segments.

Women were found to be especially sensitive to the cognitive losses due to age, particularly those over the age of 75 and those with less driving experience (11). These differences may have serious implications given that women have longer life expectancies, and that more women are expected to drive in the future (9, 20). For drivers over the age of 75, slowing of reaction time has a strong association with overall driving performance and with specific driving measures, especially those related to vehicle control. Finally, Mollenhaer et al report that navigation as a secondary driving task posed more problems for the elderly, particularly when driving in unfamiliar places – they were found to spend more time glancing at displays (11). Associated with the aging process are the "perceptual and physiological effects", fear, anxiety and vulnerability, which may cause some elderly persons to adopt some "compensatory attitudes and behaviors", some of which may have positive safety gains while others may have negative effects on safety. The ITS chapter provides more detail about ITS packages that may counteract the negative effects of the aging process, for example the availability of in-vehicle navigation systems may allay some of the fears reported. In the case of public transport services, the availability of real-time schedule and delay information may make the wait experience a more favorable one while eliminating some of the safety concerns of waiting in perceived unsafe areas for undefined periods.

3.2. MOBILITY

A common measure of mobility is the number of trips that people make away from their homes (10, 12). However, 1995 NPTS shows that mobility for elderly is getting better, since the number of trips that elderly persons make has been increasing – this is to be expected as there are larger proportions of elderly persons. In her report, Straight asserts that mobility is strongly related to driving and found that drivers made up to three times more trips than non-drivers (12). Mobility as defined above is heavily dependent on the availability of an automobile and the ability to use it. As such, the elderly are perhaps the most sensitive to the lack of this option as they in many cases, are unable to walk or use transit – either due to physical restrictions or the lack of other alternatives. Indeed Eberhardt[2] argues that elderly persons lose their ability to walk/use transit, long before they lose the ability to drive.

[2] Remark at presentation during the 81st Annual Meeting of the Transportation Research Board.

The underlying advantage of the automobile is that it accommodates disabled persons who use wheelchairs, allowing them a sense of independence, free from the hassle associated with bus/transit use. An added advantage of the automobile (for drivers of all ages) is that it allows trip chaining, thus making an efficient use of both time and resources, since several errands may be completed within the same trip. The use of public transport may be somewhat difficult for multi-purpose trips, particularly where the destination zones are far apart and not easily accessible – perhaps there are no direct connections, or a subset of the destinations have no transit available. The limitation associated with walking is more pronounced for elderly persons as walking requires that one be physically fit, and even then, it is typically feasible for short trips. Straight suggests some very simple solutions can make walking more feasible for older pedestrians - some 32-35% of elderly persons surveyed say that a resting place would enable them to walk to bus and to the grocery store (12).

Much of the focus for research on aging and transportation is on the older driver yet it would seem that the older pedestrian is more disadvantaged. In the community survey, Straight found that elderly women and low income elderly, were particularly disadvantaged when it comes to driving – more than half of elderly women had incomes less than $25,000, while of the elderly earning less than $25,000, only 68% were found to drive, while of those earning more than $25,000, 88% drove. Straight points out that more than 70% of the elderly persons over 75 live in suburbs and small towns, thus challenge for the transportation community is to find a way to support non-drivers in communities and suburbs which are "traditionally zoned" where houses are far from shops. Zhou and Lyles also expect that mobility patterns of the elderly will change – particularly since more elderly are to be found in suburban and rural areas, and not in cities or urban centers (8).

The community survey concludes that elderly persons' mobility is greatly influenced by whether or not they drive, as drivers were found to take more than three times the number of trips than non-drivers and half of non-drivers reported taking two or fewer trips per week (12). There is much concern about driver safety, particularly for elderly persons who may be faced with reduced cognitive capabilities and hence increased reaction times. ITS offers attractive solutions with proposed in-vehicle warning systems. On their part however, elderly persons also take measures to limit exposure to incidents - according to the community survey, 78% of elderly drivers were found to impose self-restrictions, by avoiding driving at night, in the rain and during rush hour.

3.3. TRAVEL BEHAVIOR

There are few studies that have attempted to predict the travel behavior of a future elderly cohort – reason being that while it may seem an attractive option; it may be rather inaccurate to predict travel behavior or transportation choices (such as mode, departure time or activity) based on dated information and behaviors may vary among different cohorts. Burkhadt & McGavock, (9) find that some factors that may influence future travel by elderly persons include the cohort effect, sex-role effect, aging in place, and that projections made about elderly travel would vary significantly depending on assumptions made about the driving behavior of older women. Indeed the gender balance/imbalance in travel demand analysis has received much attention, and with due cause – in the past fewer women were involved in the workforce – thus with increasing female employees, the number of trips made by women has increased. In addition, fewer women were drivers, but today the numbers of female drivers is almost the same as that for male drivers (for younger age groups) – thus the implications of gender for travel behavior are the subject of many studies (21).

The cohort effect, described is that today's older women drive less – this should change since future elderly women will have been driving in their youth. The sex role involves the driving behavior between couples - even among younger couples, it seems that men drive more. The aging in place effect, which is true for both males and females, implies that elderly women in suburban areas will need to continue driving. Thus the combination of these three effects has implications on travel forecasts since one can either, can assume that women will drive more, or will continue to drive less. They also mention that from 1983 to 1990, miles driven by persons over 65 plus increased 26% while from 1969 to 1990 miles driven by women increased 76% with a 35% increase for elderly women (9). As with most studies, the underlying concern is driver safety, and with projections, the implications for safety and fatality involvement rates vary with different assumptions. In spite of all the seeming uncertainty, it does seem certain that women are driving more, thus in terms of crash/fatality rates, these might be expected to increase. However, as mentioned previously, ITS is expected to play a much greater role in the preservation of driver safety, thus it cannot be determined with certainty that "…elderly traffic fatalities may be higher than the total number of traffic related fatalities", as suggested by Burkhadt & McGavock (9). They call for improvements in existing transportation systems, a move that is already underway as evidenced by the recent publication of design guidelines by the FHWA (2).

3.4. SUMMARY

This chapter has provided an overview of the literature reviewed. There is general agreement that in the future we can expect larger proportions of elderly persons and that elderly cohorts are the fastest growing age group (8, 9). Furthermore, it is generally expected that the elderly will be living in low-density areas, typically in suburbs and some in rural areas (12, 17, 22, 23). Earlier studies seem to be divergent on the question of whether future elderly persons will travel more or less than in the past. However, more recently, there seems to be general agreement that future elderly cohorts will be more active than those in the past. Studies of elderly persons travel behavior where the primary focus is not on safety are generally concerned with mobility and the influence of socio-demographic characteristics on mobility, for instance, the mobility concerns of low-income or non-driving elderly (24, 25). It is generally accepted that declines in mobility are to be expected as the ageing process occurs. However, what might the travel patterns be for those elderly who will continue to drive, or have driving as an option? This is one of many questions that a study such as that undertaken herein tries to answer. The following chapter introduces intelligent transportation systems technologies, which may increase mobility and safety.

CHAPTER 4. ITS TECHNOLOGIES

There are several studies and updates on Intelligent Transportation Systems (ITS) technologies in general. The literature on ITS is rapidly growing as more systems are deployed, and more data are collected on the various technologies. Indeed, the field of ITS is still a relatively new one in transportation. A few studies are highlighted here that pertain to an ageing population and elderly persons' mobility. For more detailed information about particular packages and for links to other sources, a recent document that focuses on ITS and the elderly driver makes excellent reading (see 18). The document, which will be included as a chapter in a forthcoming update to the 1988 TRB study on transportation for elderly persons, also indicates that the impacts of ITS on elderly driver mobility is still uncertain as there is not enough empirical evidence from which to draw conclusions.

ITS technologies offer a range of benefits to transportation systems and users – from safety improvements, to capacity increases and operational efficiencies, to environmental preservation and to the provision of information. Much of the research in ITS that specifically considers elderly persons behavior falls under human factors research and the impact that these systems may have on elderly safety, especially on elderly driver safety. It has been documented that elderly persons (perhaps due to their frailty and increased vulnerability with ageing) are three times more likely to suffer a fatality if injured in an accident than are younger drivers (18). Though safety is of paramount concern, it is not the primary focus of this study, which is the availability or provision of information through ITS technologies, and the impact that this information will have on the decision making processes and consequent travel patterns of older persons.

4.1. NATIONAL ITS ARCHITECTURE

The U.S. Department of Transportation (US-DOT) has developed a National ITS Architecture[3] to provide a common framework for planning, defining, and integrating intelligent transportation systems. The national ITS architecture was developed to support ITS implementations over a 20-year time period in urban, interurban, and rural environments across the country. The framework outlines 8 major application areas (service areas or user-service bundles), under which, 75 market packages have developed over the years. These market packages correspond to 32 user-services that ITS technologies aim to provide. The user services represent the benefits that will be derived from deployed ITS systems from the users' perspective. The main application and deployment areas are:

- Travel and Traffic Management,
- Public Transportation Management,
- Electronic Payment,
- Advanced Vehicle Safety Systems,
- Commercial Vehicle Operations,
- Emergency Management,
- Archived Data Management, and
- Maintenance Operations and Construction Management.

The market packages and user services for these application areas are outlined in the appendix. There is a continuous effort to document and estimate the benefits of ITS on transportation systems and users. Since the technologies are relatively new and are still being deployed, documented evidence of impacts to specific user groups (such as the elderly) is rather limited. Table 2 below is highlights some ITS benefits for data collected from deployments across the U.S. There have also been simulation experiments and surveys to assess the potential benefits of new ITS technologies. These form the bulk of the literature on the impacts of ITS on an elderly driver population.

4.2. ITS BENEFITS

The US DOT has outlined six major objectives to be achieved by ITS technologies: they are: i) to improve safety, ii) to improve mobility, iii) to improve system efficiency, iv) to increase productivity, v) to conserve energy and protect the environment, and, vi) to satisfy customers. Each of these objectives has its own set of criteria (MOE – measures of effectiveness) against which performance is measured. An improvement in safety is typically inferred from a reduction in crashes and/or fatalities after a given system improvement. A proxy for elderly person mobility is the number of trips taken, which has been increasing over the decades. ITS packages

[3] Source: http://itsarch.iteris.com/itsarch/index.htm, Online version of the National ITS Architecture

that have been deployed in metropolitan Texas areas will be assessed for effectiveness in aiding elderly persons' mobility and ease of use.

There is a potential to increase safety and possibly save lives, as the elderly are particularly vulnerable. These systems will reduce the task-load on the elderly driver, for instance the collision avoidance systems, or collision warning systems automate much of the driving process, and as such may serve to either prevent a possible accident or alert the driver of a looming hazard. In this way they may increase driver confidence. Similarly, the adaptive cruise control systems relieve driver task load as they adjust headway (following distance), relieving the driver's task of judging distances and speeds of the vehicles in front of them. The adaptive cruise control systems may also increase system capacity and efficiency as they minimize headway while maximizing safety – without these systems, elderly drivers, may decrease throughput due to their fear – which causes them to either drive slower, increase following distance, or both. Driver safety in rural areas may also be enhanced by the deployment of emergency alert or automatic vehicle location ITS technologies. It is reported that 93 percent more rural accidents result in deaths than do urban crashes – this is attributed to slower response times in rural areas. ITS technologies offer effective means for identifying and locating hazards in order to dispatch emergency response units in a timely fashion.

Driver confidence may also be increased by the availability of information, which may also increase elderly drivers' accessibility by offering them the convenience of in-vehicle route guidance and navigation through unfamiliar or new areas. This may increase destination options for elderly drivers, who may otherwise be limited since it is reported that they have more difficulties in route finding than younger drivers (Caird, 1999). The vision enhancement systems may also increase driver confidence, accessibility and mobility by allowing elderly drivers to drive at night or in adverse weather conditions. Below is a summary of benefits of in-vehicle ITS technologies that are particularly relevant to older drivers.

Table 1: Potential Benefits of In-Vehicle ITS Technologies[4]

In-vehicle Technology	Potential Benefits
Emergency Alert or Automatic Vehicle Location	Potential to improve emergency response in rural areas
Navigational Technologies	Aid trip planning, increase driver confidence, offer way-finding capabilities
Adaptive Cruise Control	Automates headway adjustment, offering increased safety
Vision Enhancement Systems	Aid drivers in adverse conditions or in detecting changes in the driving environment
Collision Avoidance Systems	Advance warning of potential crashes acts as safety measure

Some of the Advanced Traveler Information Systems (ATIS) packages that have been deployed include Automatic Vehicle Location, Electronic Toll Collection, Emergency Management Centers; Controlled signalized intersections with closed loop detectors, Closed Circuit TV, Variable Message Signs and Highway Advisory Radio and Internet Kiosks. Survey responses will be used to assess the effectiveness of the various technologies, and a rank ordering will be developed to gauge the relative usefulness of each package. This should aid agencies in the planning process when targeting specific community cohorts. To obtain the rank ordering, the ELECTRE methodology will be employed.

4.3. SAFETY AND MOBILITY

Much of the support for ITS is based on expectations of increased safety, mobility and generally, improvements in system performance along the six criteria outlined. However, Smiley (26) and Caird (18) point out the challenges associated with the prediction of benefits. The main argument is that benefits that accrue should be measured taking into account the effects of human behavior or behavioral adaptation to the new systems. They caution that technological improvements may lead to riskier behavior due to driver perception of increased safety or increased confidence and cites as an example when anti-lock brakes were introduced and people drove faster. She points out examples where technological improvements may lead to riskier behavior, such as when anti-lock brakes were introduced and people drove faster. Smiley (26)

[4] Summary from "Older Driver ITS" chapter, see Caird (1999) for detailed information.

suggests that there are potential trade-offs between mobility and safety that need to be considered; for instance driving faster, or in more difficult conditions or engaging in other non-driving tasks since driver workload has been reduced due to the technologies.

Table 2: Summary of ITS Benefits[5]

Program Area/Benefit Measure		Summary
Arterial Management Systems	**Safety Improvements**	Automated enforcement of traffic signals has reduced violations 20% to 75%.
	Delay Savings	Field studies in several cities have shown that adaptive signal control systems can reduce peak period travel time 5-11%.
	Customer Satisfaction	In Michigan, 72% of surveyed drivers felt "better off" after signal control improvements.
Freeway Management Systems	**Safety Improvements**	Traffic management centers using ramp meters reported freeway management systems reduced accidents 15-50%.
	Delay Savings	Advanced Traffic Management Systems (ATMS) in the Astrodome area reduced street congestion delay by 46%.
	Customer Satisfaction	After the Twin Cities ramp meter shutdown test, support for a complete shutdown fell from 21% to 14%.
	Environmental	In Denver, Colorado, dynamic message signs (DMS) that posted real-time vehicle emission levels motivated most motorists surveyed to consider repairs.
Incident Management Systems	**Safety Improvements**	In Pennsylvania, Traffic and Incident Management Systems (TIMS) decreased highway incidents 40% between 1993 and 1997.
	Delay Savings	The I-95 Traffic and Incident Management System (TIMS) in Pennsylvania decreased highway incidents 40%, and cut closure time 55%.
	Customer Satisfaction	In Puget Sound, Washington, 95% of drivers equipped with Mayday voice communications felt more secure, and 70% with text messaging felt more secure.
	Cost Savings	In New Mexico, a private ambulance company used CAD/AVL to guide ambulances to exact locations. The company increased efficiency 10-15%.
Traveler Information	**Safety Improvements**	IDAS models of ARTIMIS in Cincinnati and Northern Kentucky indicated traveler information may have reduced fatalities 3.2%.
	Delay Savings	In the Washington DC metro area, a simulation model showed that commuters who used traveler information may improve their on-time reliability 5-16%.
	Customer Satisfaction	In Philadelphia, 66% of surveyed commuters changed their departure time, and 86% changed their route as a result of a real-time traveler information.
Road Weather Management	**Safety Improvements**	In Idaho, weather-related warnings on freeway dynamic message signs decreased vehicle speeds 35% compared to a 9% decrease without the signs.
	Customer Satisfaction	In Finland, 90% of surveyed drivers felt weather controlled dynamic message signs were useful.
	Cost Savings	In Wisconsin, a snow forecasting model (with ice detection) improved DOT work schedules and reduced labor costs 4 hrs/person during significant storms.

ATIS: A “two-edged sword” for older drivers? ATIS systems are to enhance driver capability, yet as people age their divided attention capability tends to diminish. Older drivers have been found to spend more time than younger drivers accessing information from in-vehicle displays. This may have adverse consequences for the older driver and other drivers. While ITS developers are looking towards more user-oriented systems they face the challenge of satisfying the requirements of a diverse driver population. There are also trade-offs to be considered, for instance, amount of information that can be fit onto a screen versus the size of the letters. Real time traffic information may also be transmitted over the Internet.

Ramp Metering – the benefits from ramp metering accrue from accident reductions and enhanced traffic flow. The reduction in visual acuity, cognitive and physical abilities in the elderly may impact the efficiency of a ramp metering system. On the contrary, the ramp metering process may encourage driver confidence and enhance traffic flow.

Dynamic Message Signs: As with in-vehicle displays, there are trade-offs between "depth" of information provided and size of the letters. The effectiveness of DMS to relay real-time information relies on driver capability to adequately shift attention from the driving task and back to the driving task within sufficient time to make decisions.

Lane Control Signals: Lighting and size of display arrows should cater to the needs of the elderly.

4.4. ITS AND ELDERLY

Henk and Kuhn, (27) argue that the elderly are less technologically adept than younger cohorts and that therefore transportation designers need to cater to elderly persons' needs and requirements. While it may be true that differences do exist between elderly and younger persons, the apparent gap in technological awareness, comfort, or ease of use is likely to be reduced for the future elderly and even now is less than before. The technological revolution has left no one behind, regardless of race, gender, or age – it has not been limited to certain cohorts. It is however the rates of progress that differ across different population subgroups due to other constraints, particularly financial and access issues. However, as we move forward, it is expected that the apparent difficulties encountered will decrease – these differences may be attributed to the steep learning curve Nevertheless, in the next decade or two, the technologies that may be introduced may not be all too different from what is currently available, and as such should be user friendly for the elderly.

[5] Source: http://www.benefitcost.its.dot.gov, Also includes negative impacts of ITS

As far as the elderly are concerned, ATIS will prove more useful both for the urban/suburban and rural elderly. Urban dwellers may need real time traffic information while rural dwellers may be more interested in real time weather conditions and the availability of expedient EMR services. Thus the question is not 'whether ATIS will improve mobility' but 'how much' of a factor it will be in the decision making process of an elderly traveler. How can these benefits be quantified, and what impact will technology have on the trip making behavior of a 'technologically savvy' elderly cohort? What then are the policy implications per funding or legislation, such as licensing, that are likely to emerge? For one, there does not seem to be a qualitative method of assessment for elderly drivers and at present decisions are made by individuals, perhaps for high risk cases by doctors or enforcement agencies – at the extreme end. However, there is technology to aid 'lesser' impairments such as vision enhancement systems – researches have raised the question whether such technologies may actually hinder the safety element offered by these systems by giving drivers a 'false sense of security'.

4.5. SUMMARY

This chapter has introduced the merits of ITS and the challenges in evaluating benefits in the dynamic process of technology development particularly in light of the changing demographics. The potential benefits include increased systems safety, driver confidence, elderly mobility and accessibility. The following chapter gives an overview of assessment methodologies that may be used to evaluate the benefits of deployed ITS strategies.

CHAPTER 5. EVALUATION FRAMEWORK

To answer the question on how ITS can enhance elderly persons' mobility given that the society is generally aging, and that society is becoming more accustomed to technology provides a double challenge. To begin with, predicting benefits for an aging cohort that is not yet elderly entails an underlying assumption that behaviors will not change. This assumption may have serious implications. Furthermore, the technologies themselves are still developing, and as such, the effects, in many cases, are yet to be observed and fully understood. A dynamic assessment process is then needed to evaluate transportation systems for the society at large and the elderly in particular.

5.1. SAFETY AND SOCIETAL CONCERNS

With the increase in elderly persons there has also been an increase in studies related to transport safety. Among the frequently studied population groups are "young" (teenage) drivers and "elderly" drivers – typically those over 85. Elderly person concerns are also addressed with handicapped/disabled person concerns – any of these groups may be termed a "special needs group". A crucial step involved in the planning for "special-needs" groups is the identification of their needs in the first instance. Dissanayake et al (28) have suggested the use of multi criteria decision methods to identify such critical needs. This method entails the distribution of surveys to transportation professionals who each offer their subjective opinion on various questions. The authors identified six population subgroups (one of which was the elderly) and asked various questions of the engineers, which elicited the engineers' perceived vulnerability of each subgroup. Each group was assigned a ranking along a certain criterion – the authors developed an overall index, citing the most critical needs of each group. The authors' study was intended to "identify the critical population groups" via the survey – to "develop the final ranking among the identified critical issues" among each subgroup. Each criterion had several attributes (concerns) for example for highway safety the attributes associated with elderly drivers were nighttime visibility, congestion, freeway driving, maneuvering curves, perception-reaction time, gap acceptance and lane width. On the other hand the attributes for young drivers, included speeding, lack of experience, reckless driving, and immaturity among others. Using the weights, a rank ordering of the concerns was obtained. A final ranking was obtained by averaging the results of the three different weight sets. This process is useful in transportation planning of systems that are geared for diverse populations. This may also be useful in sub-systems that will attract huge crowds with various needs, such as theme parks – while safety is of the utmost concern to all, there are different ways in which to raise the safety questions and thus find appropriate countermeasures to protect users. For the elderly the top most important issues identified were i) location and size of traffic signs/lettering, ii) nighttime visibility, iii) perception-reaction time, and iv) gap acceptance. Of these, ITS technologies may improve the latter three, while roadway design considerations are necessary for traffic signs.

Once the safety needs of the elderly have been established, a methodology to evaluate the interaction of new technologies on the driving task is needed. One such method is proposed by Mattingly et al (29). They present a methodology that "yields an overall worth measure by combining preferential information from [all] actors involved in an integrated fashion with the multiple objectives and attributes". They integrate Analytical Hierarchy Process (AHP) with multi-attribute value functions using weights. While the method proposed evaluates transportation systems, this process is useful in a decision-making context where for instance a transportation agency would like to invest in infrastructure that satisfies the needs and requirements of a diverse population. In particular, the individual decision maker, the older driver benefits from evaluation of available technology when say, is deciding which of the new in-vehicle navigation systems to purchase. The agency on its part, benefits from such an evaluation, in deciding how best to disseminate information to the elderly to ease that subgroups travel, or how best to allocate its resources in order to realize optimal benefits and minimal costs – in terms of safety, the agency needs to identify packages that result in the maximum reduction of crashes and fatalities. In the larger context, the population as a whole needs to be considered, but at the planning level, benefits can be reaped from disaggregating the process. The methodology suggested by Mattingly et al, uses AHP to "address lower level" concerns while multi-attribute value functions are used for "higher level" concerns. The AHP "allows the analyst to account for the decision makers' preference structure without creating brand new value functions for every possible combination". This "universal scaling proxy allows the analyst to combine multiple distinct functions" and compare attributes that may otherwise be directly incomparable in pair-wise comparisons. The value functions establish a scale for comparing different types of data, while receiving a weighting structure from AHP. The authors' proposed method is believed to be a more efficient way of eliciting preference information while simultaneously evaluating data.

5.2. BENEFITS OF TRAVELER INFORMATION

This information may be used to help agencies identify how best to meet their constituents needs. Results obtained from a survey of both elderly and younger drivers, indicate that the most important uses of ATIS for elderly drivers were found to be for weather, traffic congestion related information and information about incidents/accidents (27). In contrast, 'younger' drivers found congestion to be very important, followed by incidents/accidents, closures then weather. Given that many elderly persons are retired and no longer working – it is possible that a large number of them travel less frequently during the peak hours and thus experience less congestion. Furthermore, the survey established that the typical response to ATIS was to change route – this was true for both age groups. Besides a change in route selection, drivers also modified their departure times. However, more elderly drivers reported changing departure time than did younger drivers. This is not surprising, since many younger drivers are workers, and whose schedules are therefore constrained by work requirements. More than half of the drivers stated that the benefits of ATIS were that it enabled them to change their schedules, save them time by allowing them to change the routes, and helps alleviate stress associated with undesired driving conditions such as congestion – with ATIS drivers are able to make travel plan changes that may eliminate the trip altogether, or may allow drivers to avoid unwanted and unnecessary adverse driving conditions.

The survey of elderly drivers directly elicits preference information from drivers, by asking questions related to an ordinal scale. From this information, manufactures are better able to market their products more efficiently if targeting this particular segment (elderly). Transport planners are also able to use this information in understanding elderly travel behavior. The survey results confirm the reality that workers face – more constraints along the temporal dimension, thus they are more likely to alter routes rather than departure times. Elderly drivers, who generally have more flexibility in their choice of departure time, may benefit from ATIS in the selection of an ideal departure time for trips. Indeed, the older drivers reported that being able to change schedules was more important to them than say, saving time, which was more important for the younger drivers.

A final step is the integration of information obtained from professionals and that from the users themselves. The information most desired by the elderly road users is of the real-time type. Perception-reaction type, gap acceptance and freeway driving are all related to traffic conditions in that elderly driver situation may be exacerbated during congestion or bad weather. From the agency perspective, weather information – along with road conditions - should be included when real-time traffic information is disseminated. From the road users' perspective, the availability of timely information enhances the quality of life through a favorable travel experience. Since many of the technologies are still in the development stage, and much data has not been collected regarding the performance of drivers using new technologies, a complete assessment is not available but for results from several simulation type studies. However, analysts are warned that drivers' adaptation to new technologies is a factor that must be considered; the technology may aid or hamper the driving task – depending on driver reaction, i.e. whether they undertake more risky behavior due to the perceived sense of increased safety from in vehicle technologies such as collision avoidance systems.

The availability of ATIS may impact the choices travelers make along several dimensions – the choice of mode, route or departure time. A discrete choice study using a simple multinomial logit model is performed to analyze the temporal travel patterns of elderly persons for recreational trips. A model including driver stated preferences was also assessed and indicates that drivers are more sensitive to congestion in the morning peak than in the afternoon peak. Elderly drivers are also concerned about ongoing roadway construction during the peak hours and more so during evening/night hours. In addition, driving through unfamiliar neighborhoods is a concern during the late night and early hours of the day. Perhaps the presence of an in-vehicle navigation system may help alleviate some of these fears while boosting driver confidence.

5.3. SUMMARY

This chapter has presented a methodology for assessing the impacts of deployed ITS strategies and benefits to users. One dimension of travel that may be impacted by the availability of advance travel information through ATIS packages is departure time. Elderly drivers reported changing departure time more frequently than did younger drivers (Henk & Kuhn, 2000). The following chapter is a study of departure time choice for elderly persons.

CHAPTER 6. DISCRETE CHOICE STUDY

6.1. BACKGROUND

The commute/work-trip has received considerable attention over the decades, in transportation research, from route choice to mode choice – there is an abundance of literature documenting the numerous studies. As transportation systems began to reach capacity, there was the evolution of flextime, telecommuting, congestion pricing, and other measures, all geared towards managing demand. The work-trip has some inherent inflexibility associated with it in that, typically, jobs start at nine and end at five as most business or commercial enterprises operate during the middle portion of the day. Therefore, many discrete choice studies have focused on mode choice – in an attempt to find a suitable answer for the peak hour congestion that is common in cities across the United States.

Recently however, non-work-trips have been receiving increasingly more attention and with this, so has the modeling of departure time choice. There is some implicit flexibility associated with the recreational trip, as it does not revolve around fixed commitments. Thus, the study of departure time choice for recreational activities helps gain an understanding for travel behavior within a different context - one of flexibility versus one of constraints and allows for an examination of the variation of travel behavior that exists between different time blocks of the day. The studies on departure time choice for non-work or recreational activities have generally been for the population at large. This study focuses on departure time choice for an elderly population subgroup.

Over the past few years, the aging of the nation has received much attention, across all fields, and in transportation field in particular. Indeed statistics indicate that the elderly form the fastest growing age group in the U.S. and in much of the developed world. Furthermore, older drivers form the fastest growing segment in terms of licensed drivers and distances driven and proportion of driving population (4).This has several implications for transportation planning in that several assumptions are made regarding the user who is typically assumed to be a healthy young male. In terms of departure time choice analysis, the consideration of larger elderly cohorts than previously existed becomes critical since many of the elderly persons will perhaps no longer be working and whose travel behavior then, is expected to differ from the rest of the population. This is a study of the departure time choices within a sample of persons aged 50 and over. The study compares the temporal preferences of persons between the ages of 50 and 64, to those of elderly persons (persons aged 65 and over, or senior citizens).

Much of the literature available regarding elderly users concerns the issue of safety and is probably warranted given the high fatality rate that elderly users experience. There is also much focus on accessibility for elderly and disabled travelers. There is however, little concerning the interaction of age and other elements of transportation such as say, emerging technologies, activity participation or travel behavior along a 24-hour time frame. At the same time, much of the departure time choice research has focused on work trips, which typically have fixed ends. More recently, there are studies such as those by Steed and Bhat (30, 31) that model departure time choice for non-work trips and studies by Bhat (32) for urban shopping trips. The study by Steed and Bhat (30) is very similar to the present study, in that they also model departure time choice for recreational trips. This work differs in that the sample is restricted to elderly persons aged 50 and over living in suburban and rural areas from a nationwide data set, while the previous study was restricted to residents of the Dallas/Fort Worth area. In addition, Steed and Bhat's (30) study introduced age as a linear variable, which may lead to shortcomings when trying to identify the special requirements of particular age groups. In their study they found nonlinear spline effects of age did not improve their model. The results of this study show otherwise.

There is general agreement that in the future we can expect larger proportions of elderly persons and that elderly cohorts are the fastest growing age group (8, 9). Furthermore, it is generally expected that these elderly will be living in low-density areas, typically in suburbs and some in rural areas (12, 17, 22, 23,). Earlier studies seem to be divergent on the question of whether future elderly persons will travel more or less than in the past. However, more recently, (perhaps due to the availability of the 1995 NPTS results) there seems to be general agreement that future elderly cohorts will be more active than those in the past. Studies of elderly persons' travel behavior where the primary focus is not on safety, are generally concerned with mobility and the influence of socio-demographic characteristics on mobility, for instance, the mobility concerns of low-income or non-driving elderly (22, 24, 25). It is generally accepted that mobility declines are to be expected as the ageing process occurs – however, for those elderly who will continue to drive, or have driving as an option, what might their travel patterns be? This is one of many questions that a study such as that undertaken herein tries to answer.

As Steed and Bhat (30) highlight in their study, the reasons for modeling departure time choice are "twofold", first because the numbers of non-work trips are increasing and are therefore likely to impact congestion and air quality. Secondly, because of the flexibility associated with non-work trips, these trips are more likely to be affected by "socio-demographic changes and transportation control measures" than work-trips. These reasons ring even more true for elderly persons, because as the numbers of elderly increases, an increase is also expected in the number of non-work trips, as elderly persons tend to be non-workers/retirees. Elderly persons may also be particularly sensitive to transportation control measures such as congestion pricing for instance, because in many cases, their income is reduced or may be low-income. In addition to these two reasons, another reason for studying elderly departure time behavior may be in order to gauge how to best offer alternative means of transport such that they will be most effective in meeting the demands of non-workers or for non-work trips.

6.2. THEORETICAL FRAMEWORK

Discrete choice models commonly employ a logit/multinomial logit functional form which is derived from the random utility maximization principle. Random utility choice theory states that individuals seek to maximize their utility and as such will choose the alternative that provides them maximum utility within a given set of alternatives. The logit formulation is a simple yet effective model with which to estimate market shares, and has been used extensively in the transportation field in travel demand management and forecasting applications. The logit model is favorable as it allows empirical analysis at the level of the decision maker – an individual, or a household, in the context of trip making or other decisions that impact travel behavior, such as vehicle ownership or residential location.

Utility theory forms the basis for much work in understanding individual behavior, and may be traced back to economic literature. Utility itself is an abstract concept that is used to represent the enjoyment that a consumer derives from use of a particular good or service. The basic premise in utility theory is that there exists a set of options (known as a choice set) among which an individual will select an alternative. The consumer will choose the option that maximizes the individual's utility. In the transportation field, utility theory is used to form the basis for analyzing traveler (consumer) behavior, in the context of choices among a finite set of mutually exclusive and exhaustive alternatives. For example, an individual's choice of mode for any given trip consists only of those feasible options – such as air, rail or auto, as in the case of a long-distance trip. If there exists no water-transport between the origin and destination, it is self-evident that water transport is not an option for that particular individual. At any given time, the individual may only use one of the modes;1 that is to say if the individual chooses air, that individual may not simultaneously use any of the remaining modes.

While in economic theory, demand for goods is modeled as continuous, in transportation, many of the choices are from a discrete set of options (such as mode, number of vehicles to purchase, or route selection). In this context, it is the probability of choice of a particular option that is estimated based on the utility maximization principle. As such, much of the work in transportation demand modeling is based on probabilistic choice theories because the utility for any alternative is a random variable, and the models predict the probability of choice of an option. The utility for any alternative can be described as having two components; a deterministic part and a probabilistic part. The deterministic part represents the utility that can be estimated from observed characteristics of the decision maker. For instance, disposable income may impact the choices a consumer makes such as in the purchase of a vehicle, and consequently in the mode options available. Many low income households do not have a vehicle available for use, and as such form a captive market for public transportation. Other measurable characteristics that may impact choices are the individual characteristics such as age, gender, employment status, and race. There are also socio-demographic variables such as residential location (urban or suburban or rural), population density, employment density, home-ownership rates and so on that are used in modeling travel behavior. There are still other variables, such as accessibility, or land use mix that are somewhat measurable or can be approximated by the use of indices. All these characteristics are included in models as explanatory variables and will form the deterministic part of utility. The deterministic part of utility implies that an individual would make the same choice given the same set of alternatives (or that individuals with similar characteristics would make the same choice given the same set of alternatives). Since these models attempt to predict human behavior, there is no reason to believe that individuals would make the same choice. Indeed the notion of rational consumerism (on which the concept of utility is based) has been challenged.

Behavioral models, which try to more closely predict human behavior, incorporate the probabilistic component of utility because utility cannot be fully described by observed characteristics. There are numerous unobserved characteristics that will influence the decision a consumer makes. For example, in transportation the utility an individual attaches to comfort (as in ride comfort, or ambient car temperature) is unobserved. Similarly, an individual's desire for peace, quiet or privacy on a trip is unobserved, and may lead one individual to prefer private transportation to public transportation, much more than another individual who has the same observable characteristics. Other unobserved characteristics include self confidence, or perceived safety which may impact a travel patterns such as avoiding the use of public transport since the transit stops are perceived as potentially unsafe environment, or increasing following distance when driving.

The assumptions about the random utility variable, lead to the multinomial logit model (MNL); namely that the "random elements of the alternatives are independently and identically distributed with a reciprocal exponential distribution" (33). The random elements of the utility variable may be described as an error term, and for the MNL it is assumed that the error term is extreme value or gumbel distributed. In much analytical work, a normal distribution is typically assumed for random variables – a normal distribution for the error term would lead to a multinomial probit model, which is more complex and more difficult to estimate and interpret. For this reason, the MNL is more commonly used, as it is much easier to implement as it produces a closed form probabilistic model. The MNL assumes that the error terms are identically and independently distributed across i) alternatives, and ii) individuals (See (34) for further discussion on the MNL). One property characteristic of the MNL model is known as "independence from irrelevant alternatives" (IIA). The IIA property causes the ratio of the probabilities of choosing two alternatives to be independent of any other alternative. This property leads to the "blue bus /red bus paradox" commonly cited in transportation literature (34).

6.3. DATA

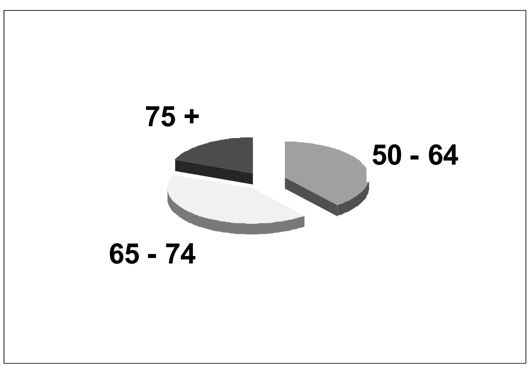
The data for this study were obtained from the Nationwide Personal Transportation Survey (NPTS) conducted in 1995 by the Research Triangle Institute (RTI) under the sponsorship of four agencies in the US-DOT; FHWA, the Bureau of Transportation Statistics (BTS), the Federal Transit Administration (FTA) and the National Highway Traffic Safety Administration (NHTSA). The NPTS "serves as the nation's inventory of daily personal travel, and is the only authoritative source of national data on daily trips" that may be used to better understand travel behavior. As the data are collected at the level of the decision maker, (the individual), the NPTS is particularly useful in disaggregate travel analyses. The NPTS was also previously conducted in 1969, 1977, and 1983, and as such may be used to identify trends in travel over time and the relationships with changing demographics. The NPTS is a survey of households, and as such does not include persons who live in institutions such as military personnel on base, college students in dormitories, prison inmates, or other group quarters. Of relevance to this study, the NPTS does not include residents of nursing homes, or assisted living facilities. As such, the mobility of elderly persons living in these facilities is not accounted for and is not included in this study.

The sample for the 1995 NPTS was selected from all 50 states, and the District of Columbia. The sample consists of all persons living in households who are 5 years of age or older. The sample size was approximately 21,000 households, with an additional 21,000 purchased by a few states. The initial sample size was chosen to provide adequate national statistics and some statistics for regions of the nation, but not to provide data at the level of the state or metropolitan area. The sampling plan was stratified sampling by Census divisions, metropolitan area size, presence of rail transit and telephone number density. The sample was controlled by geography so that data collection was spread uniformly throughout the country and across the data-collection period. Sampling was also controlled by day of week, to ensure that all geographic areas were sampled on each day of the week. Sampling was done from a modified random-digit dialing, using selections of area codes, exchange codes within area codes, and generation of random four-digit numbers (10).

All household members of the sampled households kept a travel diary for a week, documenting all trips made and trip characteristics such as trip purpose, mode used, departure time, number of people on trip and so on. Household level characteristics were also documented (income level, vehicle ownership, residential area type), as well as individual characteristics (age, gender, education level, race). The unit of analysis is the person-trip. For this study, a number of restrictions were imposed in order to reduce the over 300,000 observations in the sample to a feasible number of cases. To begin with, the study focuses only on persons aged 50 and over, as mentioned earlier, and on non-work trips. The non-work trips included in the study are shopping trips, trips to visit friends, trips to eat out and what is termed "social/recreational" trips. Thus of a total of 17 possible purposes for trips as designated in the NPTS, only four are included. In addition, only those trips taken in a privately owned vehicle (POV) were used. Furthermore, only those observations of rural or suburban residents were retained for analysis – as the indication is that baby-boomers are ageing in place – more so in suburban areas. The resulting sample consists of 1605 person-trips (cases) taken by 1174 individuals. 53 percent of the 1605 person-trips were taken by females, 26 percent by people who lived in rural areas with the remaining 74 percent in suburban areas. 51 percent of trips were taken by people who earned less than $30,000 annually, while 18 percent earned less than $15,000 annually. 57 percent of the trips involved group travel, and 28 percent took place over a weekend.

The majority of the sample consisted of a retirees: 60 percent were a couple and 20 percent were single retirees. Less than five percent (2.6 percent) of the households had children, while 11 percent were couples and 5 percent single adults. 52 percent had a high-school diploma or less, 22 percent some college education, and the remaining 26 percent had a bachelor's degree or higher. Just fewer than six percent were non-white, and fewer than ten percent (7.7 percent) reported being non-drivers. 32 percent of the households had no transit available.

Figure 4: Age Distribution



The data set is further segmented into three age bands: ages 50 – 64 (50-64), ages 65 – 74 (young-old), and ages 75 and over (75, old-old). The distribution is somewhat uniform.

Figure 5: Activity Patterns by Age

The figure on the right shows the activity patterns of the three age groups. From this we see that the old-old group primarily makes shopping trips, which are to some extent fundamental (required) trips, since grocery shopping would be included. This is expected since reduced mobility for much older persons results in reduced trip making, and as such, the more luxury or social trips would be eliminated first.

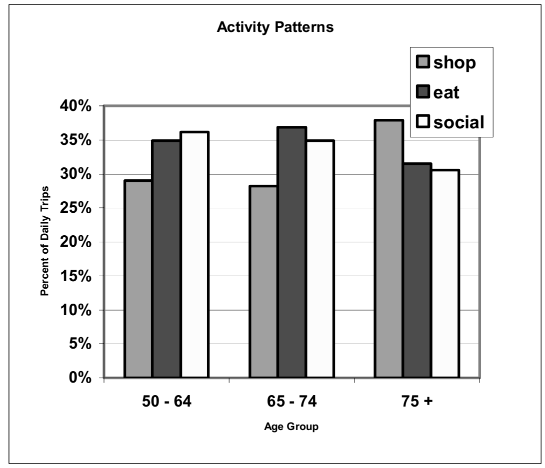


Figure 6 on the following page shows the distribution of activities throughout the day. It is evident that most activities take place in the middle portion of the day.

Figure 7 shows the departure time distribution by age group. It is clear that there is a marked decrease during the later part of the day particularly for the third age group.

Figure 8 shows the predominance of trips on weekdays rather than weekends.

Figure 9 shows that weekday trips take place earlier in the day than on weekends.

Figure 6: Departure Time Distribution by Activity

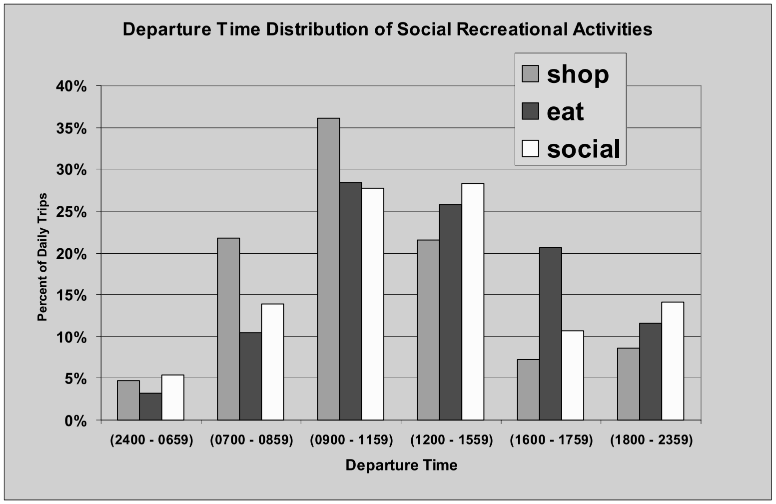


Figure 8: Activity Participation by Day of Week

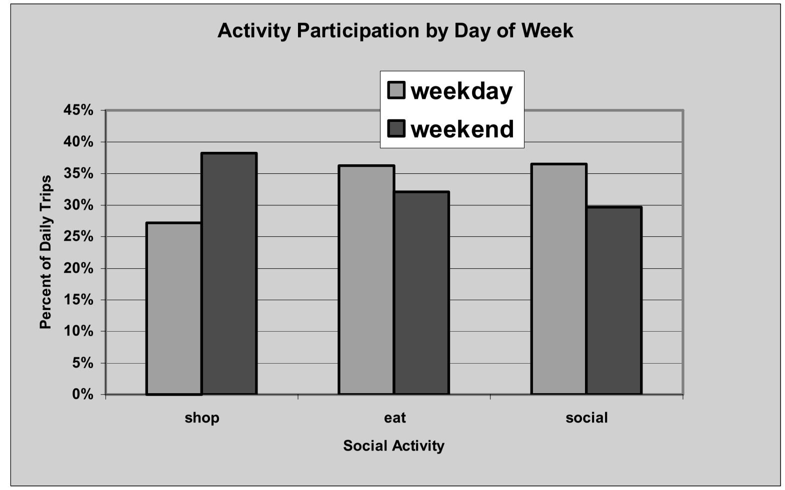


Figure 7: Departure Time Distribution by Age Group

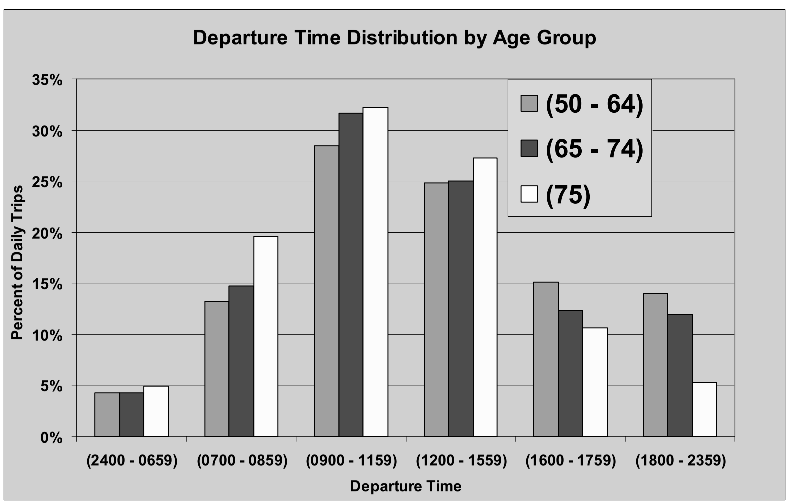
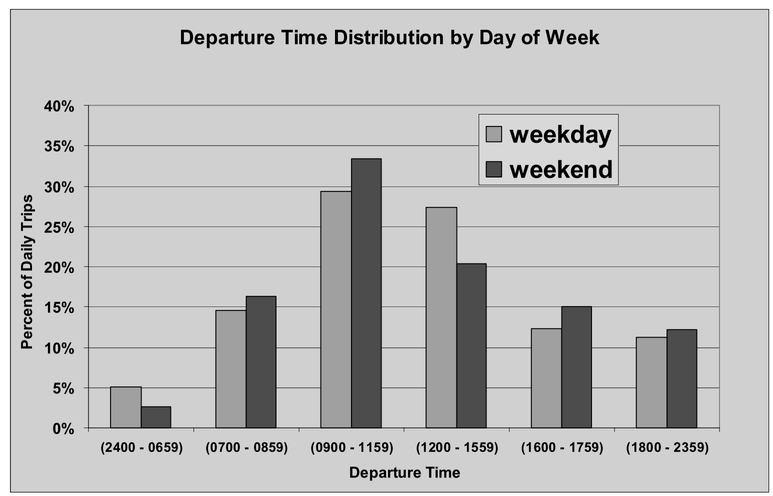


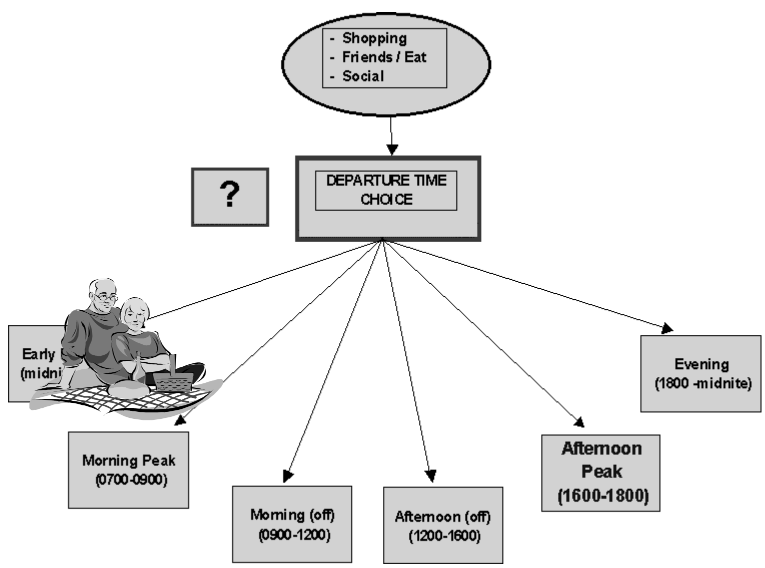
Figure 9: Departure Time by Day of Week



6.4. MODEL STRUCTURE

The first model assumes that the activity choice is predetermined and made independently of the departure time choice. There are three activity choices: (i) shopping, (ii) eating out or visiting friends, and (iii) social trips, and six departure time choices. The NPTS allows for seventeen (17) different trip purposes, only four are included herein and are collectively referred to as "recreational" trips. The four activities that are included are shopping trips, visiting friends, eating out, and "social/recreational" trips (as defined by the NPTS). For this study, two of these activities have been combined (visiting friends and eating out), thus there are three activities that are included. For the remainder of this report 'recreational' activities refers to the three types of activities collectively, while 'social' activities refers to "social/recreational" activities as defined by the NPTS.

Figure 10: Decision Process Diagram



A simple multinomial logit model was used with the dependent variable, departure time, consisting of six discrete choices. The assumptions of the multinomial logit model include the independence from irrelevant alternatives (IIA), which imposes equal cross elasticities across alternatives given a change in one alternative. For example, if congestion-pricing is introduced for the peak hours, the IIA property would suggest equal draws away from the peak periods to other time periods. This property does not allow for any correlation that may exist between time periods such as between adjacent time periods – the IIA property results in cross elasticities that imply an equal increase in the early morning, morning off-peak, afternoon off-peak and evening time periods as a result of peak-period pricing.

The 24-hour day was divided into six discrete time intervals for this study as depicted in Figure 5.

The major shortcoming of the multinomial logit model is that any changes in the afternoon off-peak departure time interval (for example) would result in proportionate draws to the remaining five alternatives. This shortcoming may be overcome by using a nested logit model, or other flexible model structures as suggested by Bhat (1998a, 1998b).

The multinomial logit also assumes that error terms are identically distributed across individuals. The probability of choice of one departure time over the others is thus obtained as:

$$P(DT_i) = \frac{\exp(V_{DT_i})}{\sum_i \exp(V_{DT_i})}$$

where i represents departure time selected.

i = 1, 2 ...6 for departure times (2400 – 0659), (0700 – 0859) …(1800-2359).

The time bands used in the analysis are as follows: early morning (2400 – 0659), morning peak (0700 – 0859), morning off-peak (0900 – 1159), afternoon off-peak (1200 – 1559), afternoon peak (1600 – 1759), and evening (1800 – 2359).

The probabilistic choice model is based on utility, which consists of a deterministic part (V) and a random part (an error term, ε). The deterministic component of utility (V) is estimated based on observed characteristics as follows:

$$V_{DT_i} = \beta_0 + \beta_1(X_1) + \beta_2(X_2) + ...\beta_n(X_n)$$

where:

β_0 is the constant for departure time i

β_1, β_2, …β_n are the parameters for the explanatory variables

X_1, X_2, …X_n are the explanatory variables (which are the observed characteristics, such as income, age etc

The explanatory variables, which were introduced as dummy variables, included:

- Activity type:
    - eating out or visiting friends
    - social
- Trip characteristics:
    - group travel/traveling alone
    - weekday/weekend travel
- Family structure characteristics:
    - presence of kids
    - retired persons
- Individual characteristics:
    - gender
    - race
- Age-related variables
    - young-old (ages 65-74)
    - old-old (ages 75 and over)
    - senior citizens (ages 65 and over)
- Socio-demographic characteristics
    - income (low income, high income)
    - residential area (rural/suburban, MSA type) .

The model assumes the afternoon off-peak as the base departure time, against which other time intervals are compared. In addition, when comparing across activities, the shopping trip was used as the base, and as such shopping was not included as a variable. Parameters for interactions of the various variables were also estimated (for instance, the interaction of female, old-old, traveling in groups or traveling on the weekend).

6.5. RESULTS

A final specification was achieved by following a stepwise analysis. Several model specifications were tried but many variables were not significant, such as the presence of young children – which is not too surprising since the sample consisted only of elderly persons aged 50 and over, and contained very few households with young children. The variables that were considered relate to socio-demographic characteristics. Of the constants, the only positive one is the morning-off peak constant, which shows the general preference for earlier part of the day travel as opposed to later travel.

The results are shown in Table 3. The Log Likelihood at Zero is (-2645.834), and the Log Likelihood at Convergence is (-2513.488).

The base alternative was the afternoon off-peak time interval; all other departure time choices were compared against this base. The co-efficients (parameters) estimated in the model are used to predict the utilities for each of the alternatives following the form in equation (*5b*). The premise is that individuals will select that alternative that provides them the maximum utility. As shown in Table 3, the co-efficient for afternoon-peak is (0.0). Negative signs indicate a lower likelihood of choice than for the afternoon peak. For example, (-1.66) means that persons were less likely to choose the afternoon peak than the afternoon off-peak departure time and furthermore, that persons were *least* likely to select the afternoon peak of all the alternatives (six departure time intervals) as this constant is the smallest in magnitude. On the other hand, (0.23) means that persons were more likely to choose morning off-peak over all other alternatives, including afternoon off-peak, as this is the only positive constant.

Table 4 shows the corresponding utilities, as obtained from Table 3, for individuals whose personal and trip characteristics may be described as shown by the column heading. The table values in turn correspond to values of utility within a matrix representing the effects of interactions of explanatory variables with the time alternatives. A simple example is the case of weekend travel, say for a shopping trip in the morning off-peak.

As mentioned earlier, persons were more likely to choose the morning off-peak departure time (0.23). Note that for weekend travel, persons are more likely to choose morning off-peak than afternoon off-peak, and even more likely to choose morning off-peak departure time than on weekdays (1.71) for shopping trips. The value of utility (1.71) is determined as follows:

$$V_{DT_i} = \beta_0 + \beta_1(X_1) + \beta_2(X_2)$$

where:

DT_i in this case is the morning off-peak

β_0 is the constant for the morning off-peak

β_1 is the estimated parameter for the activity variable (in this case, shopping, and is therefore zero since shopping was the base)

X_1 is the dummy variable for activity selected (shopping)

β_2 is the estimated parameter for the explanatory variable (in this case, weekend travel)

X_2 is the dummy variable for weekend travel

it follows:

$V_{\text{am\_off-peak, shop, weekend}} = (0.23) + (0)*(1) + (1.48)*(1) = (1.71)$

Since the parameter for weekend morning off-peak (value of 1.48 from Table 3) is positive, morning off-peak on weekends is preferred to afternoon off-peak on weekends. Remember that shopping in the afternoon off-peak was selected as the base, thus the constant for afternoon off-peak is always zero, and the parameter for the shopping activity is also always zero. Furthermore, when comparing the departure time selection across days of the week, note that the utility for shopping on the weekend during the morning off-peak (1.71) is greater than the utility for shopping on a weekday during the morning off-peak (0.23), which is just equal to the constant for morning off-peak (see Table 4 for easy comparison).

As with the shopping trip, morning off peak is preferred to afternoon off peak departure for eating out or visiting friends. On the other hand, note that the morning off-peak on weekends is less desirable than the morning off-peak on weekdays for the other two activities, more so for social activities. In addition, the morning off-peak is less desirable than the afternoon off-peak for social activities on the weekend. The respective utilities are obtained in a similar manner as shown above. Thus, for eating out or visiting friends, the morning off-peak (0.2) is preferred to the afternoon peak, while for social activities, the morning off-peak (-0.13) is less desirable than the afternoon off-peak – perhaps there are more social activity destination options available in the afternoon than in the morning. At the same time, for both types of activity (eat/visit and social), the morning off-peak on weekends is less likely to be selected than the morning off-peak on weekdays, as in both cases the utility for weekend morning off-peak is lower than the utility for weekday morning off-peak (0.23). Note that the utility for weekday morning off-peak for all activities is the same, as the model did not estimate any significant parameters to differentiate between activities for weekday morning off-peak travel.

For the shopping trip, note that while morning peak travel is less desirable (-0.13) than afternoon off-peak travel on *weekdays*, there is a change in signs for *weekend* travel – in fact, persons are more likely to choose morning peak travel (1.35) than afternoon off-peak travel. This is understandable as the congestion attributable to commute trips during the week is absent on weekends and travel routes are presumably carrying less traffic. In addition, the model suggests that elderly persons may represent "early birds" who go shopping earlier during the day on weekends, to avoid crowds or to get the best value for money spent as in fresh produce. As shown in the previous example, the utility for weekend morning peak travel for shopping trips is obtained similarly:

$$V_{DT_i} = \beta_0 + \beta_1(X_1) + \beta_2(X_2)$$

where: DT_i in this case is the morning peak

β_0 is the constant for the morning peak

β_1 is the estimated parameter for the activity variable (in this case, shopping, and is again zero since shopping was the base)

X_1 is the dummy variable for activity selected (shopping)

β_2 is the estimated parameter for the explanatory variable (in this case, weekend travel)

X_2 is the dummy variable for weekend travel

it follows: $V_{\text{am-peak \& weekend}} = (-0.13) + (0)*(1) + (1.48)*(1) = (1.35)$

On the other hand, note that the utilities for weekend morning peak travel for the other activities are still negative, that is weekend morning peak is still less desirable than weekend afternoon peak travel for eat/visit or social trips. Furthermore, morning peak travel is less desirable on the weekend than weekday morning peak travel for eat/visit or social trips. This may be because crowds in shopping venues are less desirable than crowds at social venues, or that the “early bird” specials that are available at shopping destinations do not apply for the other activities.

Table 4 is a matrix of the estimated utilities for various interactions of the explanatory variables. The values in the columns are obtained by summing the corresponding estimated parameters that are presented in Table 3. For instance, the final specification indicated that retired persons were only more sensitive to the evening and afternoon-peak departure times. This means that retired persons were as likely as non-retired persons to choose the other four departure times. However, to determine the likelihood that retired persons will select an evening departure time for the shopping trip, the coefficients in Table 3 are manipulated as such:

$$V_{DT_i} = \beta_0 + \beta_1(X_1) + \beta_2(X_2)$$

(-1.25) = (-0.69) + (0)*(1) + (-0.56)*(1)

where; (-0.69) is the constant, and (-0.56) is the estimated parameter for the retired persons selecting the evening departure time.

This means that retired persons are even less likely than non-retired persons to select an evening departure time.

Following is an explanation of the results from the final specification:

Day of Week

Weekend shopping activities are more likely to take place in the morning than on weekdays. However, eating or ‘social’ activities are less likely to take place in the morning on weekends than on weekdays, and less likely to take place on weekend mornings than shopping on weekend mornings. The positive shift for shopping on weekend mornings may perhaps be due to reduced congestion on weekends. The negative shift for eating or ‘social’ activities may be due to the fact that these activities typically involve other people, and considering that it is during the weekend, the other members of the group could perhaps be ‘young-old’ persons, who were found to generally prefer later activities. Shopping during the afternoon peak is more likely on weekends than shopping on weekdays during the afternoon peak. There were no significant shifts observed for the other two activities other than the negative shifts for morning activities.

Family Structure

Retired persons seem more likely to participate in 'recreational' activities during the afternoon peak, than non-retired persons. However, retired persons were less likely to participate in evening activities than non-retired persons. Perhaps the retired persons find the afternoon peak a suitable bridge between the morning and evening

Trip Characteristics

Group 'recreational' activities were less likely to take place in the early morning or morning off-peak than non-group activities. Group activities were however, more likely to take place in the afternoon-peak and evening time periods than non-group activities. This could be due to the fact that groups could contain "younger" persons who generally tend to prefer 'later' activities. Also, since the group coefficients were for all days of the week – it makes sense, as some of the group members could be workers, who only have time for 'recreational' activities after their workday has ended.

Individual Characteristics

Females were much less likely than males to take part in early morning 'recreational' activities. This could be due to safety (perceived or real) concerns. This could also be due to other responsibilities that females may have that males do not, such as household chores, cooking or caring for other members of family. Blacks seemed to be less likely than other races to participate in morning off-peak 'recreational' activities. However, Blacks and Asians in groups were more likely than other races to take part in evening 'recreational' activities – this may be representative of true population preferences. It has already been mentioned that groups may tend to prefer activities in the later part of the day compared to solo-travelers. In addition, these groups may consist of persons younger than 50 and/or workers (not included in the study). This may represent some cultural differences, for example many [Caucasian] families have dinner at 5pm or 6pm, other cultures may eat much later than that.

Table 3: Final Model Specification Results, Dependent Variable = Departure Time

Departure Time	Coeff.	t-ratio	P-value
Early Morning	-0.94	-4.88	0.00
Morning Peak	-0.13	-0.78	0.44
Morning Off Peak	0.23	2.18	0.03
Afternoon Peak	-1.66	-6.70	0.00
Afternoon Off Peak	0.00	Base	Base
Evening	-0.69	-3.67	0.00
EXPLANATORY VARIABLES			
Activity			
eat pm peak	0.86	4.68	0.00
eat early am	-0.48	-1.68	0.09
eat or social am peak	-0.74	-4.06	0.00
Day of Week			
weekend morning (7am to noon)	1.48	6.65	0.00
weekend pm peak	1.54	4.56	0.00
Family Life Cycle			
retired evening	-0.56	-3.13	0.00
retired pm peak	0.40	1.88	0.06
Trip Characteristics			
group early am	-0.65	-4.13	0.00
group after 4pm (1600–2359)	0.61	3.95	0.00
group am off	-0.24	-1.70	0.09
Individual Characteristics			
females early am	-0.65	-2.55	0.01
blacks and asians evening	0.77	1.96	0.05
blacks am off	-0.97	-1.73	0.08
Age			
ages 65 – 74 am peak	-0.38	-2.15	0.03
ages 65 – 74 pm peak	-1.01	-4.32	0.00
ages 75+ after 4pm (1600-2359)	-0.77	-4.16	0.00
ages 65 and over peak	0.80	4.00	0.00
INTERACTIONS			
Day of Week & Activity			
weekend social morning (0700-1159))	-1.84	-6.39	0.00
weekend, eating morning (0700-1159)	-1.51	-5.28	0.00
weekend eat or social pm peak	-1.54	-4.18	0.00
weekend social early morning	-0.75	-1.39	0.16
Age & Activity			
ages 65 – 74 eat peak	0.74	2.95	0.00
* worry congestion, am peak	0.37	2.57	0.01

Log Likelihood at Zero (-2645.834), Log Likelihood at Convergence (-2513.488)

Table 4: Deterministic Portion of Utility for Departure Time *X* as Obtained from Final Specification

		Constant	**Weekend**	**Retired**	**Group**	**Females**	**Black**	**Black/ Asian Group**	**ages 65 to 74**	**ages 75 +**
Shop	Early morning	-0.94	-0.94	-0.94	**-1.59**	**-1.59**	-0.94	-0.94	-0.94	-0.94
	Morning Peak	-0.13	**1.35**	-0.13	-0.13	-0.13	-0.13	-0.13	**0.30**	-0.13
	Morning Off Peak	0.23	**1.71**	0.23	**-0.01**	0.23	**-0.74**	0.23	0.23	0.23
	Afternoon Off Peak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Afternoon Peak	-1.66	**-0.12**	**-1.25**	**-1.04**	-1.66	-1.66	-1.66	**-1.86**	**-1.62**
	Evening	-0.69	-0.69	**-1.25**	**-0.08**	-0.69	-0.69	**0.00**	-0.69	**-1.47**
Eat	Early morning	**-1.42**	-1.42	-1.42	**-2.07**	**-2.07**	-1.42	-1.42	-1.42	-1.42
	Morning Peak	**-0.87**	**-0.90**	-0.87	-0.87	-0.87	-0.87	-0.87	**0.29**	-0.87
	Morning Off Peak	0.23	**0.20**	0.23	**-0.01**	0.23	**-0.74**	0.23	0.23	0.23
	Afternoon Off Peak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Afternoon Peak	**-0.79**	**-0.80**	**-0.39**	**-0.18**	-0.79	-0.79	-0.79	**-0.26**	**-0.76**
	Evening	-0.69	-0.69	**-1.25**	**-0.08**	-0.69	-0.69	**0.00**	-0.69	**-1.47**
Social	Early morning	-0.94	**-1.69**	-0.94	**-1.59**	**-1.59**	-0.94	-0.94	-0.94	-0.94
	Morning Peak	**-0.87**	**-1.23**	-0.87	-0.87	-0.87	-0.87	-0.87	**-0.44**	-0.87
	Morning Off Peak	0.23	**-0.13**	0.23	**-0.01**	0.23	**-0.74**	0.23	0.23	0.23
	Afternoon Off Peak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Afternoon Peak	-1.66	**-1.66**	**-1.25**	**-1.04**	-1.66	-1.66	-1.66	**-1.86**	**-1.62**
	Evening	-0.69	-0.69	**-1.25**	**-0.08**	-0.69	-0.69	**0.00**	-0.69	**-1.47**

For instance, a female 70 year old going out to eat on a weekend: utility_(early morning) = -2.07 = (-0.94) + (-0.48) +(-0.65)

Age

This study found that persons aged 65 to 74 (young-old) were more likely than others in the sample to take part in morning peak 'recreational' activities. This cohort was also more likely to eat in the afternoon peak than others in the sample. However, this cohort was less likely to shop or participate in 'social' activities in the afternoon peak than others in the sample. The 'old-old' (ages 75 and over) were more likely to participate in afternoon peak activities but less likely to participate in evening activities.

Summary

The utilities for each alternative are shown in Table 2 above, with differences highlighted. For instance, the table shows that retired persons are less sensitive to afternoon peak travel but more sensitive to evening travel. It also shows that weekend 'social' trips quite unlikely to take place in the morning perhaps due to influence from others not included in the sample. However, the interaction between weekend and group turned out to be insignificant, as did other interactions. The income variable was not significant in this study.

CHAPTER 7. POLICY IMPLICATIONS AND CONCLUSIONS

7.1. POLICY IMPLICATIONS

The results of the preliminary study lend empirical support to the notion that elderly road users exhibit different travel patterns from the general population. While "younger" persons (perhaps because the majority are involved in daily work activities or other fixed commitments such as school) seem to prefer the later part of the day for recreational trips, elderly persons favor the earlier part of the day. Thus, indiscriminate planning may not meet the needs of all users – be it transportation planning, community planning, or resource allocation in the case of a transit agency for example.

That elderly persons prefer the earlier part of the day, particularly on weekdays has implications for the transportation system – for instance with the projected increases in elderly persons and subsequently more retired/non-working persons, there may be noted increases of roadway usage during the day. From a systems standpoint, this could be viewed both positively and negatively; positively in the sense that increased usage during off-peak hours may tend to minimize the underutilization of resources (infrastructure), negatively in the sense that increased usage may require additional resources, such as emergency response services or exhaust non-renewable resources such as air quality due to increased vehicular emissions.

The expected increase of automobile usage may have some severe environmental implications – for instance in non-attainment cities, an increase in vehicle emissions during the middle portion of the day may seriously exacerbate existing poor air quality conditions. Understanding the travel needs of an increasing population segment such as the elderly will be useful in tailoring programs that have been traditionally geared towards reducing vehicular demand – an example is transit.

For transit agencies, this study may be good news in that increased off-peak demand may be better suited for taskforce management and scheduling. At the same time, in their marketing efforts, transit agencies may benefit from these findings by targeting specific market segments – such as the elderly. In order to maximize transit usage by the elderly, an understanding of elderly travel patterns is required. The modeling of mode-choice is a useful tool in understanding the factors that influence transit use. The modeling of departure time is particularly useful in trying to maximize on resource allocation and revenue collection. The availability of suitable transport alternatives, such as transit at the times they are most needed, may serve as an incentive to switch modes from the predominant privately owned vehicle. (On the other hand, there is no reason to expect elderly persons (or any other population segment that has access to an automobile) to switch modes, particularly for the non-work trip. As it is, even in cities that have "excellent" (comparatively) public transport connections, transit has paltry market shares, even for the work-trip. Nevertheless, it is worth a try, and there has to be a starting point. It would benefit transit agencies, or community transport agencies to offer alternative transport in the earlier part of the day.

For land-developers or community planners, departure time choice analysis is a useful tool in that it helps in attraction-end planning. For instance, many 'social/recreational' venues might be available to the public only during the later parts of the day (for example bowling alleys). With the expected increase of recreational trips on weekdays during the day, it would be useful to know what kinds of activities elderly persons engage in and at what time they participate in those activities. This study has provided half the answer.

7.2. CONCLUSIONS

This has not been an exhaustive study into the decision-making and travel patterns of elderly persons, but rather serves as a preliminary analysis into the behavior of an increasing segment of the population along one dimension – a 24-hour time frame. Nevertheless, some important findings have been observed during the study, in particular that elderly persons are especially prone to take recreational trips during the day. More research is needed to augment these preliminary findings. For instance an interactive process may be developed as in the example provided by Kraan et al (34) (real time en-route information to assess route switching behavior). In the case of a departure time study, an interactive method could assess the switching propensities due to real time traffic information.

In further studies, elderly workers might also be included. While this study lends useful insight into the departure time choice for elderly persons, it was limited due to time and model program constraints to suburban/rural residents only. Though we expect these areas to have increasing proportions of elderly persons, urban areas for instance could be studied as these areas have typically been residential choice areas for certain population segments, such as low-income, or non-white races. In addition, significant investments have been allocated for transit in urban areas.

A significant omission from this study is the effect of Level of Service variables. As mentioned earlier these were not available. Though LOS variables are particularly useful in mode-choice studies, these would be helpful in departure time studies in assessing the effects of a time-related change in LOS such as say peak-hour congestion. This is hardly a trivial concern even though the study concerns non-work trips. The inclusion of LOS variables will help evaluate the sensitivities of travelers to cost changes for instance, particularly since privately owned vehicles are the predominant mode, it is likely that a departure time switch would occur before a modal switch. This brings up the issue about model structure. Since a simple multinomial logit model was assumed here the IIA property holds, and as such, we cannot allow for correlation between alternatives, say for instance a stronger preference for morning travel than for afternoon travel. Future work may further the analysis herein contained, and change not only the variables that are included, but also the model structure, to say a nested logit for instance, that would accommodate what is likely a more realistic scenario where correlations do exist between alternatives.

Finally, elderly drivers reported valuing information about weather conditions (younger drivers did not tend to value this information as much). This is not a typical variable in modeling analyses. The potential of ATIS systems in this regard may assist drives who are already away from home in making decisions about their return trip. The initial individual (driver) decision of whether or not to invest in ATIS/in-vehicle systems, depends upon the subjective evaluation of various packages against individual criteria such as: costs, type of information provided, detail of information, ease of use of system, legibility of in-vehicle display units, and other more subjectively perceived benefits such as increased confidence. The day-to-day decision is a more dynamic process (once the information regarding traffic/weather conditions has been obtained) in that decisions are made as the information is received. For pre-trip and en-route information, drivers may alter routes, or switch destinations (assuming of course flexibility which is likely to be the case for elderly drivers, unless the trip is to a fixed commitment such as a doctor's appointment). In the case of pre-trip information, departure time may be modified or the trip may be cancelled altogether, whereas en-route information may cause drivers to abort the trip. At the agency level, decisions to be made include the allocation of resources, for example, emergency response units or the dissemination of the information itself.

APPENDIX A. USER SERVICES IDENTIFIED FOR THE NATIONAL ITS ARCHITECTURE

User Service Bundle	User Service
Travel And Traffic Management	Pre-Trip Travel Information En-Route Driver Information Route Guidance Ride Matching And Reservation Traveler Services Information Traffic Control Incident Management Travel Demand Management Emissions Testing And Mitigation Highway-Rail Intersection
Public Transportation Management	Public Transportation Management En-Route Transit Information Personalized Public Transit Public Travel Security
Electronic Payment	Electronic Payment Services
Commercial Vehicle Operations	Commercial Vehicle Electronic Clearance Automated Roadside Safety Inspection On-Board Safety Monitoring Commercial Vehicle Administrative Processes Hazardous Material Incident Response Commercial Fleet Management
Emergency Management	Emergency Notification And Personal Security Emergency Vehicle Management
Advanced Vehicle Safety Systems	Longitudinal Collision Avoidance Lateral Collision Avoidance Intersection Collision Avoidance Vision Enhancement For Crash Avoidance Safety Readiness Pre-Crash Restraint Deployment Automated Vehicle Operation
Information Management	Archived Data Function
Maintenance and Construction Management	Maintenance and Construction Operations

APPENDIX B. MARKET PACKAGES IDENTIFIED IN NATIONAL ITS ARCHITECTURE

Traffic Management	Network Surveillance Probe Surveillance Surface Street Control Freeway Control HOV Lane Management Traffic Information Dissemination Regional Traffic Control Incident Management System Traffic Forecast and Demand Management Electronic Toll Collection Emissions Monitoring and Management Virtual TMC and Smart Probe Data Standard Railroad Grade Crossing Advanced Railroad Grade Crossing Railroad Operations Coordination Parking Facility Management Regional Parking Management Reversible Lane Management Speed Monitoring Drawbridge Management
Public Transportation	Transit Vehicle Tracking Transit Fixed-Route Operations Demand Response Transit Operations Transit Passenger and Fare Management Transit Security Transit Maintenance Multi-modal Coordination Transit Traveler Information
Traveler Information	Broadcast Traveler Information Interactive Traveler Information Autonomous Route Guidance Dynamic Route Guidance ISP Based Route Guidance Integrated Transportation Management/Route Guidance Yellow Pages and Reservation Dynamic Ridesharing In-Vehicle Signing
Advanced Safety Systems	Vehicle Safety Monitoring Driver Safety Monitoring Longitudinal Safety Warning Lateral Safety Warning Intersection Safety Warning Pre-Crash Restraint Deployment Driver Visibility Improvement Advanced Vehicle Longitudinal Control Advanced Vehicle Lateral Control Intersection Collision Avoidance Automated Highway System

Commercial Vehicle Operations	Fleet Administration Freight Administration Electronic Clearance Commercial Vehicle Administrative Processes International Border Electronic Clearance Weigh-In-Motion Roadside CVO Safety On-Board CVO Safety CVO Fleet Maintenance HAZMAT Management
Emergency Management	Emergency Response Emergency Routing MAYDAY Support Roadway Service Patrols
Archived Data Management	ITS Data Mart ITS Data Warehouse ITS Virtual Data Warehouse
Maintenance & Construction Operations	Maintenance & Construction Vehicle Tracking Maintenance & Construction Vehicle Maintenance Road Weather Data Collection Weather Information Processing and Distribution Roadway Automated Treatment Winter Maintenance Roadway Maintenance and Construction Work Zone Management Work Zone Safety Monitoring Maintenance & Construction Activity Coordination

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