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ANALYSIS OF OLDER DRIVER SAFETY INTERVENTIONS: A HUMAN FACTORS TAXONOMIC APPROACH

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ABSTRACT

The careful application of human factors design principles and guidelines is integral to the development of safe, efficient and usable Intelligent Transportation Systems (ITS). One segment of the driving population that may significantly benefit from ITS is older drivers. The population of older drivers is steadily increasing and concerns pertaining to their needs, capabilities-and limitations will likely intensify (1). Though older drivers are under-represented in crashes and fatalities relative to their numbers in the U.S. population, their ***per mile*** crash involvement and fatality rates are higher than other driver segments (2). To address issues related to older drivers, a tool has been developed to categorize a spectrum of countermeasures: ***a taxonomy of safety interventions.*** This taxonomy provides a framework for examining the problems and research directions associated with nine primary areas of focus: (1) Driver Licensing, (2) Driver Training/Counseling, (3) Crashworthiness/Occupant Protection, (4) Post-Crash Medical Care, (5) Behavioral Medicine, (6) Fitness-For-Duty (FFD), (7) Environmental Issues, (8) Cooperative Systems, and (9) Vehicle Design/Crash Avoidance. The taxonomy is structured such that consideration can be given to each primary area independently and in relation to other primary areas. Consideration of each area independently, and how they interact with other areas, may lead to more comprehensive countermeasures. The applicability of ITS crash avoidance technology for older drivers can be addressed in this context. Given the reduction of sensory, perceptual, cognitive, and motor capabilities that are associated with aging, designing in-vehicle ITS for older drivers is apt to be challenging. ITS technology has the potential to be a "double-edged sword" for the older driver; systems that are designed to assist in safe driving may also add mental and physical workload and confusion to the driving task. Consideration of older driver issues, and the utilization of a user-centered design approach, may aid in the realization of ITS goals and objectives, making them safe, efficient and usable for both younger and older drivers.

The objectives of Intelligent Vehicle Highway Systems (IVHS) technology include: improving safety, energy efficiency, and economic productivity, as well as reducing congestion and environmental impact (IVHS America, 1992) (3).

INTRODUCTION

The careful application of human factors design principles and guidelines is integral to the development of safe, efficient, and usable Intelligent Transportation Systems (ITS). One such human factors principle prescribes a ***user-centered*** approach to design, an approach that focuses on the system's end-users early in the design process (4, 5). One of the first steps for the ITS designer employing a user-centered approach would be to define and characterize end-users. This characterization should include consideration of the abilities and limitations of the entire range of anticipated users. In the ITS arena, the range of users includes both younger and older drivers. This paper is concerned with the enhancement of older driver safety using a user-centered taxonomic tool.

Background

The U.S. population is steadily aging. Statistics indicate that those over 65 constituted 8.2 percent of the population in 1950 and 12.6 percent in 1990 (1). Projected growth rates suggest that the over 65 population will grow to 13.9 percent in 2010 and 21.1 percent in 2030 (1). Data on licensed drivers show a similar trend. Drivers over 65 accounted for 7.6 percent of licensed drivers in 1965, 11.9 percent in 1985, and 14 percent in 1993 (6, 7). Based on these statistics, we can expect older driver safety concerns-to. intensify over the coming decades.

This paper examines some of the issues pertaining to ITS development and deployment as they may impact the older driver population. As a tool to structure these issues, and allow for their individual and joint consideration, a ***taxonomy of safety interventions*** is presented. This taxonomy was specifically developed to address older driver issues, but it could also be used to address concerns related to other driver populations, including younger drivers, impaired drivers, and drivers in general.

Purpose

There are four primary goals of this paper:

- ***Consider older driver crash involvement -- statistics*** on the rapidly increasing number of older drivers are presented, along with data on their crash involvement and typical unsafe behaviors. Additionally, the crash scenarios most problematic for older drivers are described (e.g., intersection left turns).

- ***Introduce a taxonomy of safety interventions as a tool for investigating issues specific to the older driver population --*** the individual components of the taxonomy are described along with their associated primary problems and potential research directions.

- ***Outline the results of an effort to identify principal current and near-future older driver highway traffic safety research needs and targets of opportunity using the taxonomy --*** the resulting research needs are limited to human factors issues pertaining to Vehicle Design/Crash Avoidance and related areas.

- ***Outline several crash countermeasures currently being researched and developed, and assess their applicability to the needs, capabilities, and limitations of the older driver population --*** the overall purpose will be to provide a broad basis for addressing future older driver safety interventions.

OLDER DRIVER CRASH INVOLVEMENT

Older drivers are ***under*** represented in crashes and fatalities relative to their numbers in the U.S. population. In 1993, drivers aged 65 and above constituted 14 percent of licensed drivers, but represented only 7.8 percent of drivers involved in crashes and 10.8 percent of drivers involved in fatal crashes (7). The nature of the older driver crash problem is apparent when one looks at crash involvement and fatality ***rates per mile driven.*** Beginning at about age 60, the rate of crash involvement per mile traveled increases and continues to increase markedly for drivers in their seventies (figure 1) (2). Statistics show that the crash involvement rate of 80-84 year-olds is 2.4 times that of the driver population as a whole and the rate for drivers age 85+ is 6.2 times higher (8).

The amount and type of driving also changes with age. Beginning in their fifties, drivers decrease the number of miles driven and certain types of driving (9). "Difficult driving" such as driving during rush hour, night driving, and winter driving decreases. These trends continue with increasing age (10): Decreases in overall and high-risk exposure result in a lower crash likelihood (probability of involvement) for older drivers as compared to the general driving population (figure 2) (2). Note in figures 1and 2, younger drivers are more apt to be involved in crashes, whether the metric is crash involvement rate or likelihood.

An analysis of 1990 CARDfile (a comprehensive aggregated data file of all police-reported crashes in six states) shows that a high percentage of older driver crashes involved two vehicle Intersection/Crossing Path (ICP) scenarios. occurred during the daytime (especially non-rush hour, 9 AM-3 PM), involved the pre-crash maneuver of turning, involved a right-of-way violation, or disregard for a sign/signal. In contrast, a relatively low percentage of older driver crashes involved Rear-End, Head-On, or Single-Vehicle Roadway Departure (SVRD) crash scenarios, occurred at night, or involved overtly-unsafe driving behaviors such as alcohol/drug use, speeding, following too closely, or other reckless driving.

Figure 3 shows crash involvement rates per 100 Million Vehicle Miles Traveled (VMT) by age group for the three most common types of crashes: Rear-End, ICP, and SVRD. The largest increase from the middle age rates occurs for ICP crashes. ICP crash involvement rates are more than twice as high for drivers aged 75+ as for drivers aged 25-54. An implicit but unverified assumption of this analysis is that exposure to each of these crash categories is proportional to total VMT for each age group.

Other data elucidate the nature of the ICP crash problem for older drivers. Three major subtypes of ICP crashes are Signalized Intersection Perpendicular Crossing Path (SI/PCP) crashes, Unsignalized Intersection Perpendicular Crossing Path (UI/PCP) crashes, and Left Turn Across Path (LTAP) crashes (figure 4). For all three subtypes, older drivers are involved primarily as the driver of the "subject" vehicle, the vehicle making the crossing path maneuver and, when a crash occurs, the vehicle usually considered to have violated the right-of-way. For example, figure 5 shows that the increase in LTAP involvement rate for older drivers is almost entirely due to an increase in subject vehicle involvement (i.e., left-turning vehicle versus vehicle going straight).

Analysis of UI/PCP crashes in Michigan, revealed two major patterns of driver error/violation with distinct age-related differences (11). First, offending drivers went through stop or yield signs without ever stopping; only 10 percent of these drivers were over age 60. Second, offending drivers stopped at the sign and then pulled out into approaching traffic; 69 percent of these drivers were over age 60. These errors imply that older drivers obey stop signs and other traffic control devices, but have trouble with dynamic, traffic-related, information processing demands at intersections. Analysis of UI/PCP crashes (involving all driver age groups) found "looked but did not see" as the principal error (12). Earlier analysis of crash causes by age found "looked but did not see" to be the error most highly over-represented by older drivers (13). Older drivers also show increased rates of backing and lane change/merge crashes, two crash types for which "failure to perceive" is the predominant error (14.15).

TAXONOMY OF SAFETY INTERVENTIONS

A ***taxonomy of safety interventions*** was developed to address these older driver crash issues, and facilitate the identification of specific countermeasures (figure 6). Based on a review of the older driver literature, nine primary areas of focus were identified: (1) Driver Licensing, (2) Driver Training/Counseling, (3) Crashworthiness/Occupant Protection, (4) Post-Crash Medical Care, (5) Behavioral Medicine, (6) Fitness-For-Duty (FFD), (7) Environmental Issues, (8) Cooperative Systems, and (9) Vehicle Design/Crash Avoidance.

Driver Licensing

Research indicates that contemporary licensing practices may be ill-suited for detecting age-related changes affecting driving performance (16). Age-related visual impairment trends include increased sensitivity to glare, decrease in visual acuity, the need for greater illumination. difficulty adapting to darkness and brightness, altered color perception, and narrowing field of vision (17). In addition to general trends with aging, there is also increased variability among older persons (18). Interventions at the licensing level are restricted because discrimination cannot be legally based on overt group characteristics.

Crash risk is increased by medical conditions such as dementia, heart disease, diabetes, and stroke (19). Musculo-skeletal problems (e.g., arthritis) may also increase crash risk, when they restrict the ability to reach controls or see mirrors (20). Undiagnosed conditions can have symptoms equal to or greater than those diagnosed.

Driver licensing is a difficult and often politically sensitive issue. The efficacy of current licensing and testing procedures is increasingly questionable (21). Research suggests that procedures for testing driving competence, for both older and younger drivers, be developed to integrate the most valid functional measures into a short, dynamic perceptual/cognitive test battery (21). With the introduction of ITS, we might expect tasks associated with driving to change or become more complex {e.g., operating a in-vehicle navigation system, viewing a Head-Up-Display (HUD). To be effective, future testing procedures will need to account for effects that in-vehicle and out-of-vehicle ITS might have on the driving task.

Driver Training, Information, Counseling

Closely related to driver licensing issues are those pertaining to driver training, information, and counseling. These services may have potential as cost-effective safety interventions. Research in this area suggests that drivers, both young and old, can be aided by a variety of licensing, information, and counseling programs (22). but supporting effectiveness data are limited (23).

Before the effectiveness of driver training and skill augmentation can be determined, a number of issues require consideration. For example, despite research suggesting mediation of crash risk through training and education, there is no established mechanism to ensure enrollment of those drivers who could be helped. Additionally, research has yet to determine the efficacy of counseling and retraining programs. Research to determine how many older drivers have stopped driving, due to safety considerations that could be alleviated through training, also remains to be conducted (22).

As with driver licensing, targeung one segment of the driving population for training and counseling (i.e., older drivers) would be seen as unfair and discriminatory. Considering that younger drivers (i.e., teenagers) account for the highest crash likelihood involvement, improving traffic safety in general would not be best served by focusing on older drivers. It has been suggested that training, restraining, and counseling programs be viewed as an ongoing process that continues after licensing so that benefit is provided to all drivers (22).

Crashworthiness/Occupant Protection

Research indicates that older drivers are more likely to suffer permanent impairment or death in an auto crash (24, 25). Specifically, data shows that the risk for 70 year olds is nearly three times that of 20 year olds (24). This is due to physiological changes with age, allowing bones and other tissues to break with less force and circulatory problems to impair healing. Mackay (25) notes that impact tolerances are lower for older individuals. Consequently, occupant protection devices that are designed with a single condition and tolerance cannot be expected to equally protect all populations.

It has been suggested that further research is required to assess the effectiveness of occupant protection devices for the older population. Mackay (25) proposes several research directions, including an investigation of current occupant protection policies and their suitability for the older population. Mackay also suggests that research is required to improve safety-belt system design and side impact crash protection to meet the biomechanical characteristics of the elderly.

Post-Crash Medical Care

Age is a key factor in determining the outcome of crash trauma. For example, similar types of crash injuries result in longer recovery times for older individuals. Injuries categorized as AIS-3 results in an average of 9.7 days of hospitalization for an individual under 50 years of age and 13.7 days for those over 69 years of age (AIS refers to the Abbreviated Injury Scale that classifies severity using a six point scale) (25).

Cifu (26) describes a geriatric rehabilitation approach for treating the older crash victim. Utilizing an interdisciplinary team, geriatric rehabilitation works to identify and evaluate problems, set therapeutic goals, and undertake intervention. Cifu notes that in treating the elderly crash victim, an assessment of functional skills (e.g., self-care, mobility, communication, cognitive, and psychosocial skills) is critical before the patient resumes driving. Both a Functional Independence Measure (FIM) that tests basic physical and cognitive abilities, and a written and performance driving test, culminate treatment.

Strategies for rehabilitating older crash victims, and preparing them to return to driving, have not been well studied (26). However, research indicates that aggressive trauma care plays a significant role in the rehabilitation of elderly trauma victims and increases their chances of returning to independent living (27). Further research is required to investigate how rapid and aggressive medical intervention, combined with post-rehabilitation training and fitness-for-duty assessment, can be used to safely retum older crash victims to driving.

Behavioral Medicine!

Many disease processes affecting cognitive, sensory, and motor processes are prevalent in the older driver population (28, 29). Deficits in these areas, among other things, have been linked to increased risk for traffic accidents (20). In response to these and other ailments, the elderly are often prescribed medications that can lead to decrements in coordination, attention, and motor skills. For example, benzodiazepines and cyclic-antidepressants have been shown to adversely affect older driver safety (29). Highlighting this issue, Cartwright (30) conducted a survey which examined medicine taking by older individuals. Physicians were found to often prescribe medications that could affect driving performance without clear determination of the patient's driving status.

These findings suggest that further surveys of both the physician and elderly patient are required to assess the scope of this problem. Data generated from this research could be structured into education and intervention programs that target both elderly drivers and their physician. Further research might also explore interactions between the multiple factors associated with disease states and how these affect driving (e.g., daily variation and medications).

Fitness-For-Duty

Older individuals often face day-to-day variability in functional competencies that may influence safe driving. Smith, Meshkati, and Robertson (18) note that within-person variability is particularly present in persons with medical disabilities common at old age, such as stroke, heart conditions, dementia, Parkinson's disease, and diabetes. Driving tests for licensure, unfortunately, cannot adequately capture these day-to-day variations. However, empirical studies have demonstrated that functional competence can be assessed on a daily basis using cognitive and perceptual-motor tests (31, 32). While these tests are not diagnostic of the source of impairment, they are sensitive to variations in functional competence that can lead to diminished on-the-job performance (e.g.. driving).

FFD assessment technology has been successfully used in driving applications (33). Performance based ignition interlock devices, for instance, have proven effective in reducing arrests among chronic DWI offenders (34). Further studies are required to identify means of assessing a driver's real-time mental state as it relates to driving performance, and whether these may be incorporated into: (1) continuous or on-line FFD assessment while driving and/or (2) continuous tailoring of crash-avoidance and other systems (e.g., Automatic Vehicle Control Systems and Advanced, Traveler Information Systems).

Environmental Issues

Environmental issues include those related to roadway geometry and traffic control devices. Older diivers often report difficulty in driving at nighttime, in congested areas, on freeways, and in construction zones (35). Research suggests that these difficulties arise from a combination of decreased speed of mental operations and increased subjective task complexity (36).

Examples of environmental-related research directions that are outlined in the literature include: (1) suggesting that research focus on the least capable drivers currently licensed so as to better accommodate older drivers, and (2) recommending that traffic control devices be evaluated using a model-based design approach to account for both perceptual-cognitive deficits possible in older and other drivers, and interactions with in-vehicle interventions (e.g., 35, 36, 37). It is suggested that roadway geometry applications and traffic control devices will be most effective if designs include consideration for the needs, capabilities and limitations of older drivers.

Cooperative Systems

Combining in-vehicle technology with roadway sensors, warning beacons, and intelligent traffic control points can have mixed effects on safety (3). For example, a "cooperative systems" approach may introduce conflicting in-vehicle and out-of-vehicle information. This conflict may consequently negate potential safety benefits for older or other drivers with restricted attentional capacities. Alternately, cooperative system concepts have the potential to enhance the performance of older drivers (e.g., reduce perception-reaction time). For example, cooperative intersections that adaptively change traffic lights in anticipation of potential crashes could be designed with consideration for older drivers, and their related difficulties in navigating intersections. Unfortunately, few studies related to cooperative systems exist due to the prototype status of this technology. One exception is the relatively well-developed research pertaining to Advanced Traveler Information Systems (ATIS) (e.g., 38). Though cooperative systems may provide mobility and safety benefits for drivers, it is critical that they be designed for (1) the full-range of driver capabilities, including those represented by the older driver and (2) interactions with other systems. The ability of older drivers to extract information'from in-vehicle and out-of-vehicle displays requires particular consideration.

Vehicle Design/Crash Avoidance

Vehicle Design/Crash Avoidance can be broken into five taxonomic sub-areas: (I) visibility-related interventions, (2) conspicuity-related interventions, (3) collision warning systems, *(4)* other crash avoidance countermeasures, and (5) general in-vehicle display/control issues. Each of these sub-areas can be examined independently within the context of Vehicle Design/Crash Avoidance.

Visibility-Related Interventions

Visibility interventions include those that pertain to age-related declines in the visual system and are of particular importance to in-vehicle system design and traffic safety. Obviously, the ability of the driver to see the roadway environment is an essential component of crash avoidance, and interventions to boost visibility are particularly important for older drivers. Low- and high-technology interventions are both possible, but an appropriate design for the older driver is required to realize their potential. There are many unanswered questions regarding maximizing design features to accommodate older drivers, despite past research in this area (e.g., 39).

Consnicuitv-Related Interventions

Conspicuity, or being easily seen by other drivers, is also critical to crash avoidance.

Several studies have investigated conspicuity-related issues (e.g., 40, 41). Exterior vehicle modifications which promote earlier detection by other drivers may be effective crash avoidance interventions. For instance, lights and signals on the vehicle, if designed with consideration for visual and other limitations, may increase conspicuity and reduce the risk for collision.

Collision Warning Svstems

It is beiieved that in-vehicle collision warning systems will have a significant impact on crash reduction (42). This belief is based upon a growing body of analytic studies and early-prototype demonstrations (e.g., 42, 43). In concept, collision warning systems have the potential to augment human sensory capabilities and redirect attention so as to reduce the frequency and severity of automobile crashes. However, decreases in sensory, attentional and other capabilities associated with aging may also translate into reduced capabilities to respond to such augmentations.

Other Crash Avoidance Countermeasures

In addition to collision warning systems, other ITS devices have the potential to reduce crashes (e.g., Automatic Vehicle Control Systems [AVCS]). Though full-scale engineering prototypes exist for AVCS technology (e.g., lane tracking), few driver acceptance or human factors studies exist due to its prototype status (e.g., to evaluate accompanying driver underload). ITS has the potential to improve traffic safety, but the long term "subjective responses" to new technologies and the impact of decreased sensory and attentional capabilities of older drivers remain to be addressed in design-related research.

General In-vehicle Display/Control Issues

Numerous in-vehicle display/control issues have been examined in the literature (e.g., 31, 44). To date, this research suggests that we might expect advanced technology in-vehicle systems to include displays and controls that are novel or particularly difficult for older drivers to use. To avoid overloading the older driver, sensory, perceptual, cognitive, and motor capabilities should be addressed early in the design process. Many relatively basic aspects of display presentation have not been resolved for older drivers. Examples include digital versus analog presentations and degree of acceptable clutter. Research might also focus on how advanced technologies affect older driver performance (e.g., HUDs, proprioceptive displays. softkey and voice controls).

APPLICATION OF TAXONOMY OF SAFETY INTERVENTIONS

The outlined taxonomy was recently used to identify principal current and near-future older driver highway traffic safety research needs and targets of opportunity (Bittner, Hanowski. Byrne & Parasuraman, 1994, unpublished). The application of this taxonomy was useful in identifying 62 ***elemental research needs*** which were later integrated into 15 ***research directions*** and, ultimately, nine prospective ***principal research needs. This*** effort was limited to potential human factors needs specific to Vehicle Design/Crash Avoidance and its related taxonomic areas (i.e., Fitness-For-Duty, Cooperative Systems, and Environmental Issues). Each prospective need was identified, scaled, and ranked based on estimated near-term potential and relative value in providing crash avoidance and safety for older drivers. The result of this effort was the identification of five primary, and four secondary, research need areas of opportunity.

The five primary areas of opportunity were:

- ***HUD guidelines for older drivers***
- ***In-vehicle warnings, guidance, and collision aids***
- ***Driving-related perceptual and motor variability in the older driver***
- ***Older driver vehicle illustrative guidelines and prototype development***
- ***Vehicle conspicuity and lighting.***

The four secondary research need areas of opportunity were:

- ***Older drivers and advanced technology***
- ***In-vehicle navigation aids***
- ***Mirrors and visibility extension tools***
- ***Vehicle control***

Supporting the comprehensiveness of the approach, several of the identified primary and secondary areas were already being addressed in on-going programs. Additionally, other needed areas of opportunity pointed toward requirements to augment or emphasize older driver concerns in ongoing and future planned ITS research (particularly with regard to interactions between taxonomic areas). The taxonomy was consequently found to be an effective tool for identifying the breadth of older driver safety interventions.

ITS CRASH AVOIDANCE AND APPLICABILITY TO OLDER DRIVERS

Current research addresses a wide variety of high-technology crash avoidance devices aimed at supplementing driver perception, judgement, and control. Such systems may be classified conceptually in three intensity-of-action categories (45):

- ***Advisories –*** systems that inform the driver of a situation that has the potential for producing a collision, but not requiring an immediate collision avoidance action (e.g., advisories of current headway, indicators of a vehicle in an adjoining lane, advisories of reduced roadway friction, advisories of driver drowsiness or other impairment).

- ***Warnings –*** systems that warn the driver of an imminent collision and elicit collision avoidance action (e.g., obstacle detection systems). Such systems may exhort the driver to perform a specific action (e.g., "Brake!") or provide a non-specific warning signal such as a buzzer.

- *Automatic control* -- systems that actuate a specific vehicle control action when a collision is imminent (e.g., braking). The need for such responses may be based on the failure of the driver to take appropriate action (perhaps following a prior advisory or warning), or may be based on a kinematic determination that immediate vehicle response is required to avoid a crash.

Concerns regarding older driver capabilities are posited to be relatively low in relation to automatic control, moderate in relation to advisories, and high in relation to warnings. The concern is relatively low in relation to automatic control, since automatic vehicle control is intended to eschew human capabilities. Of course, startle reactions, or other disrupted driver performance after the actuation of automatic control, may still be a particular concern for older drivers.

Advisories are intended to avoid crash-imminent situations where dynamic driver performance (e.g., brake reaction time) is critical to crash avoidance. These systems require driver perception of an advisory and a decision to comply with it, possibly a problem for some older drivers who lack vehicle situational awareness (e.g., drivers who currently fail to perceive turn signal indicators). Compliance with a perceived advisory is less likely to be a special concern for older drivers as they tend to be more compliant than other drivers (11).

The highest level of concern regarding the application of ITS to older driver collision avoidance may be in the area of collision warnings. The performance capabilities of older drivers may often fall short of levels necessary for successful crash avoidance. For example, given a warning signal to brake, older drivers are likely to react less quickly and exert less brake pressure than younger drivers, affecting the probability of collision avoidance (43). Consequently, older drivers may be expected to benefit less from such countermeasures under equivalent circumstances than would younger drivers. Future systems can be made adaptive to driver capabilities (e.g., greater warning distances/times for slower-reacting drivers), but this could be at the expense of more false alarms and lower overall system performance.

It is recognized that lTS technology has the potential to be a “double-edged sword” for the older driver. On one side, ITS devices -- such as obstacle detection/warning systems -- are designed to supplement driver perception, and “failure to perceive” is a common error associated with older driver crashes. On the other side, older drivers may not be able to use warnings as effectively as other drivers. Further, their performance could be degraded at times due to associated distraction, information overload, or an adverse panic reaction. The types, amounts, and the methods of presenting information must be carefully studied to ensure that older driver Safety is enhanced rather than degraded by ITS.

SUMMARY

This paper has considered older driver crash involvement, and presented a taxonomy for organizing research and addressing safety interventions (with particular focus on in-vehicle crash avoidance devices). Issues raised that may be of particular interest to the ITS community include:

- *Older drivers are at particular crash risk when their attentional and other dynamic informution processing capabilities are most challenged (e.g., during left turn maneuvers).*

- *In-vehicle crash avoidance and other systems have the potential of being "double-edged swords" that increase challenges to limited capabilities they are nominally designated to augment.*

- *Taxonomy-based analysis can be effective in identifying significant opportunities for older driver safety intervention and research to realize these opportunities.*

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LIST OF FIGURES

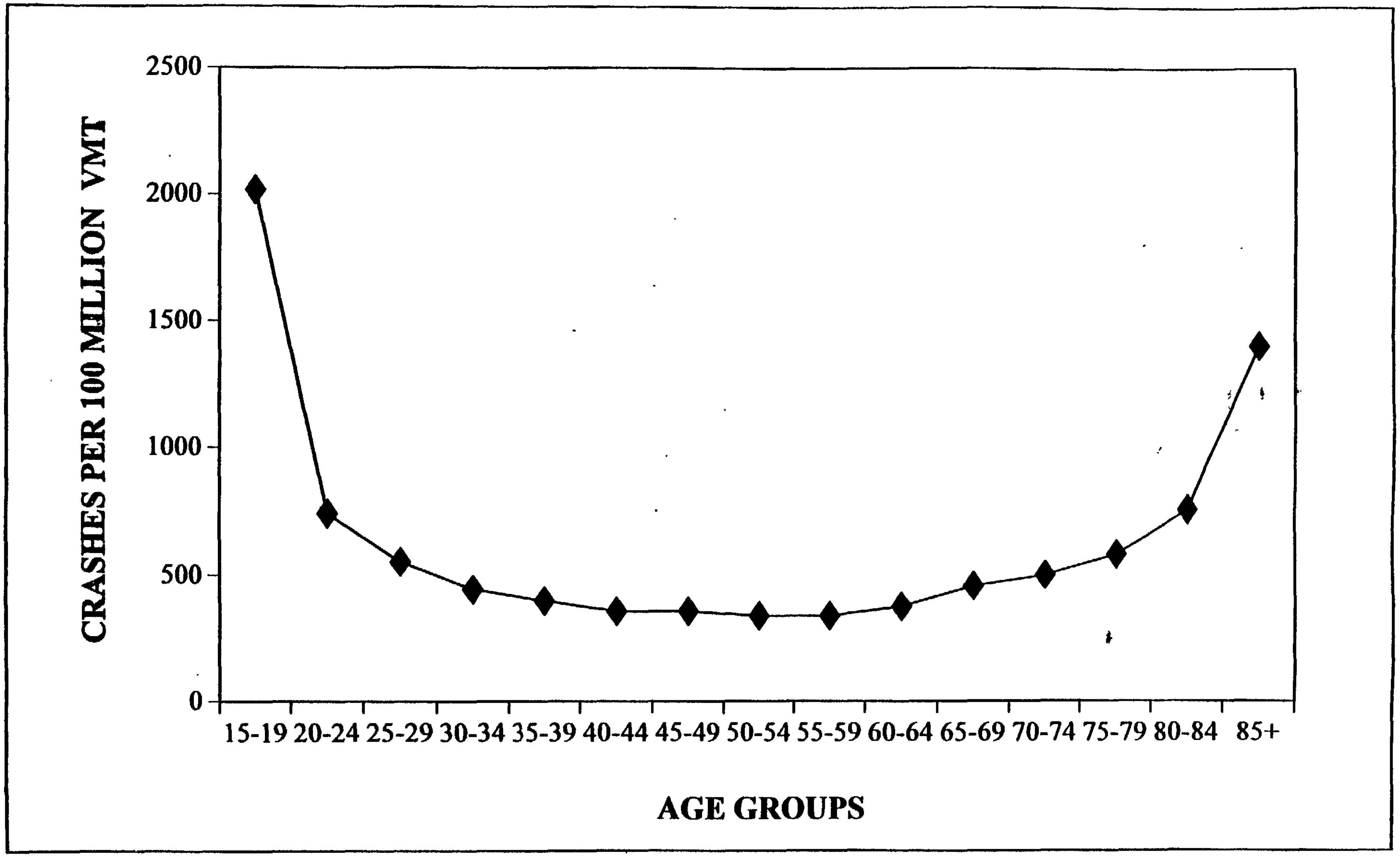

Figure 1. Crashes per 100 million VMT (vehicle miles traveled) by age.

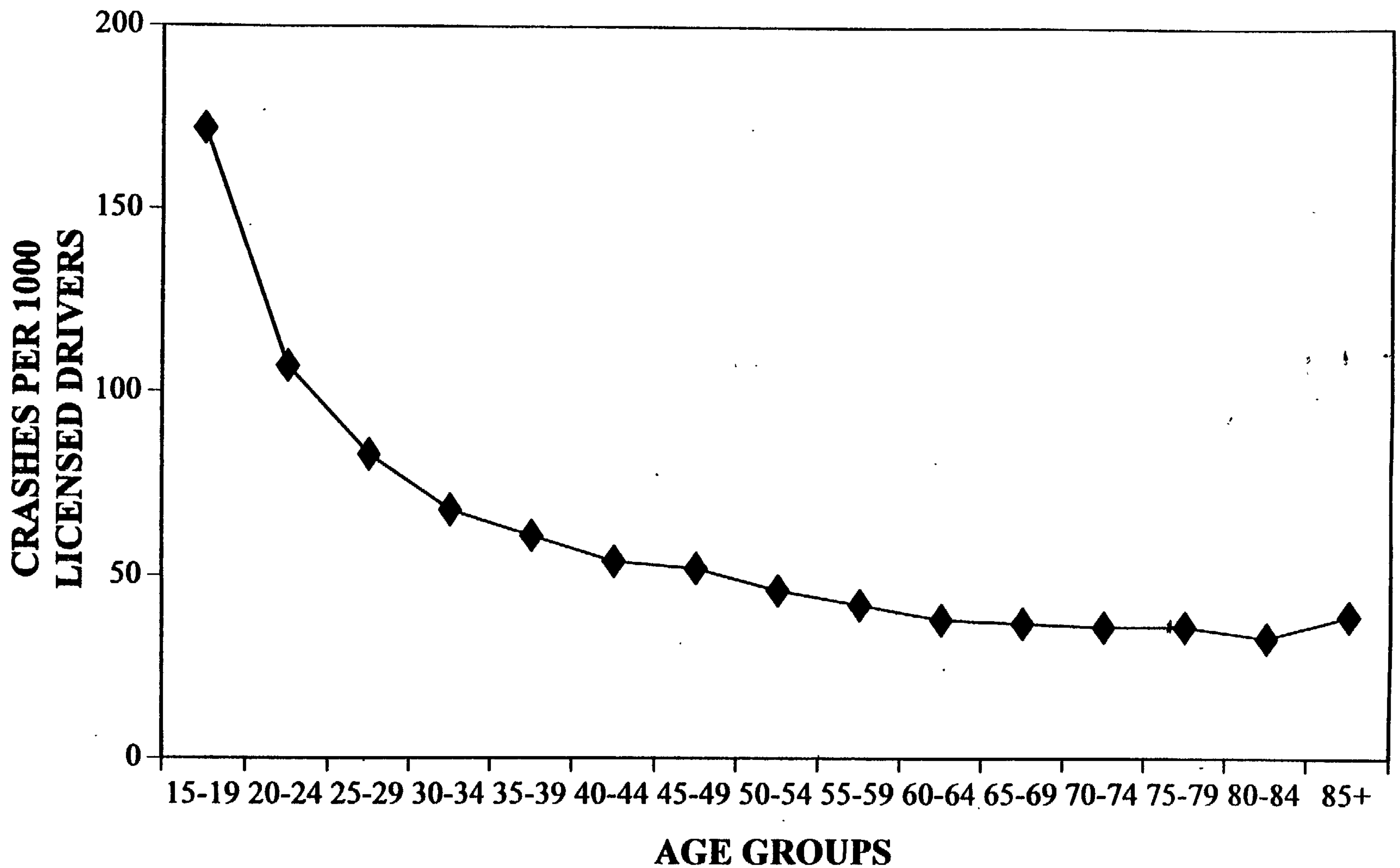

Figure 2. Crashes per 1000 licensed drivers by age.

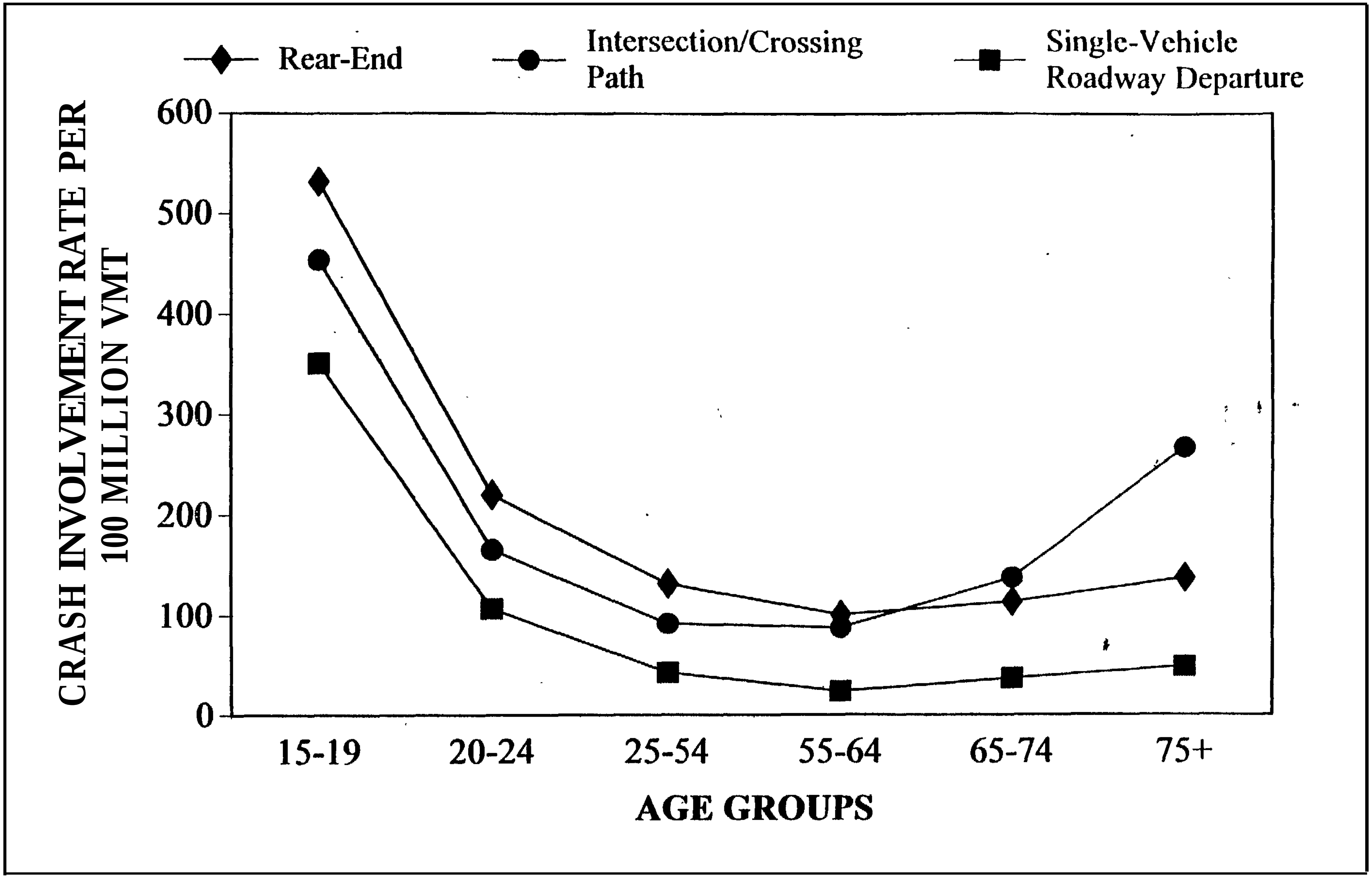

Figure 3. Crash involvement rate by age group as a function of Rear-End, Intersection/Crossing Path (ICP) and Single-Vehicle Roadway Departure (SVRD) scenarios.

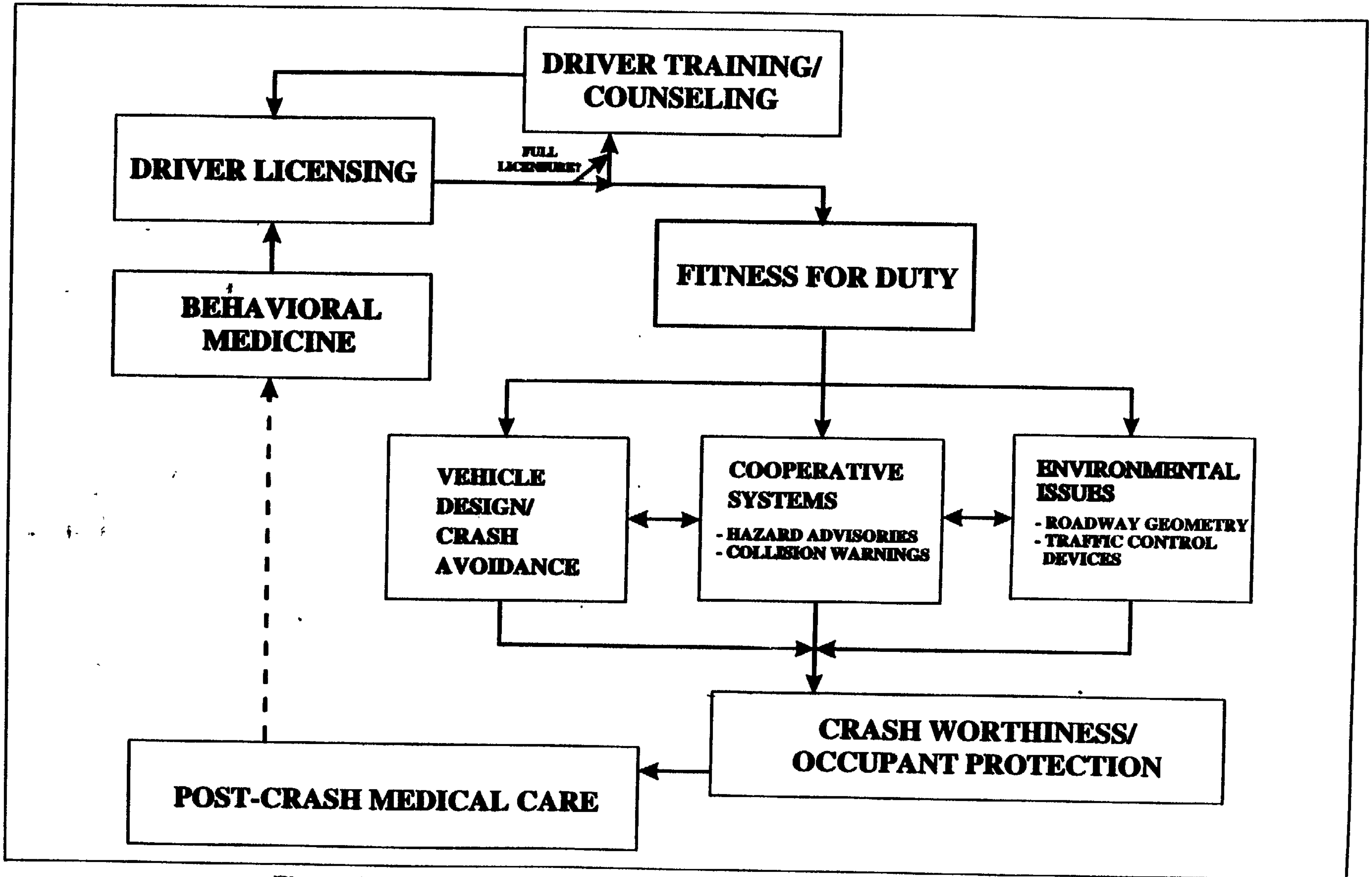

Figure 6. A taxonomy of safety interventions relevant to the older driver.

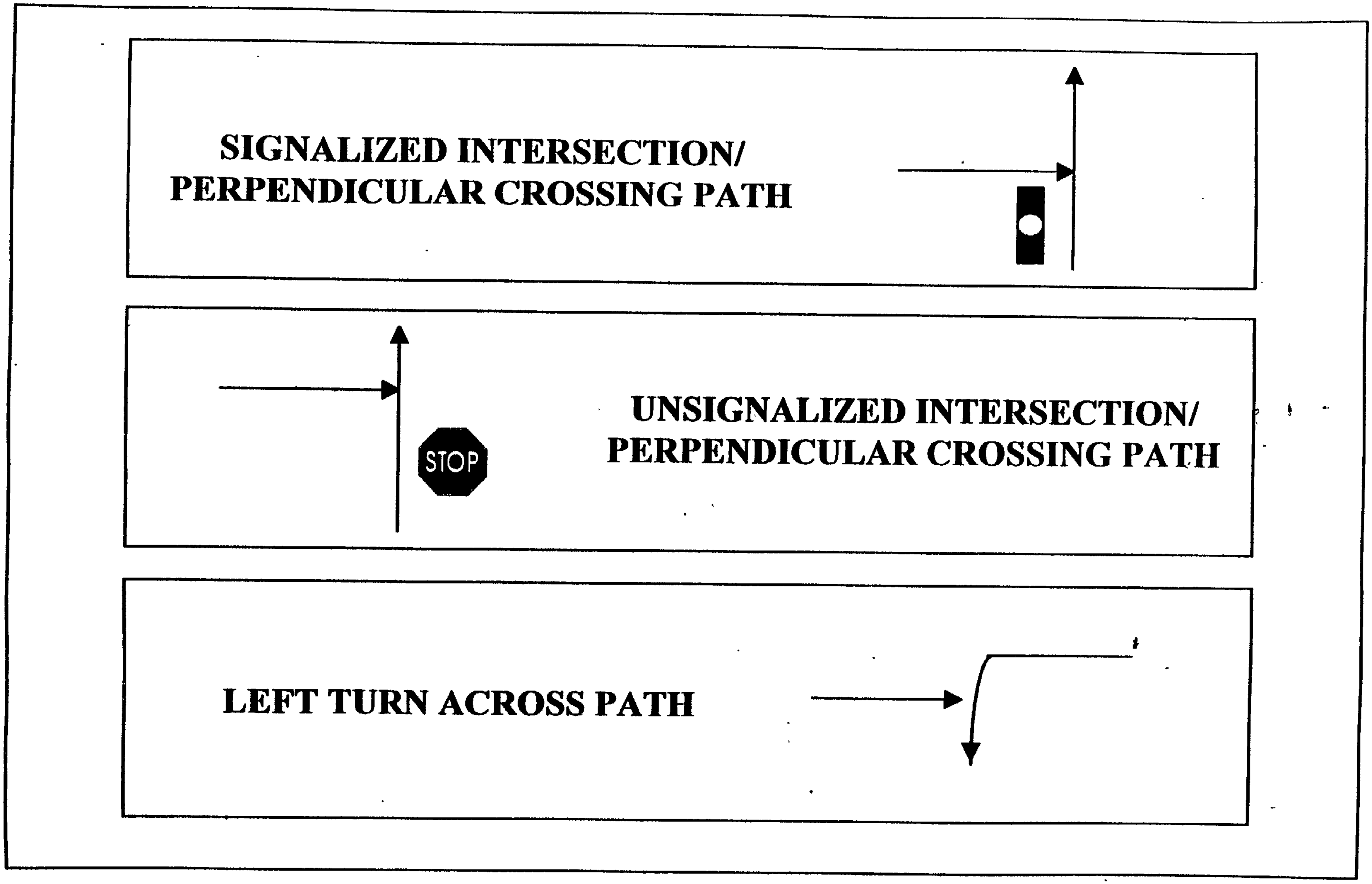

Figure 4. Principal intersection/crossing path crash types.

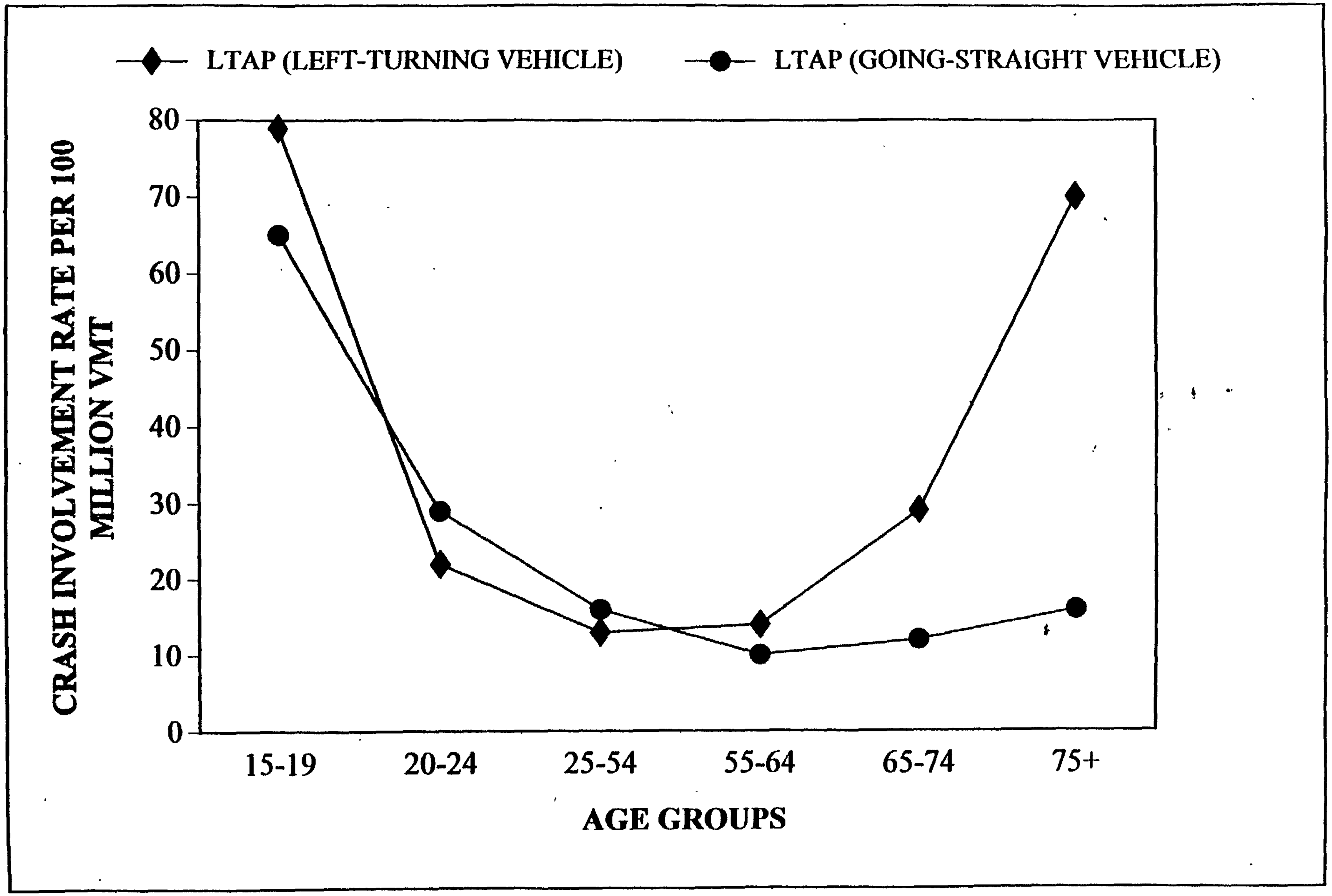

Figure 5. Crash involvement rate by age group as a function of Left-Turning Across Path (LTAP) left-turning vehicle and LTAP going-straight vehicle scenarios.