

**TOWARDS MODELING THE IMPACT OF AN AGEING DRIVER
POPULATION ON INTERSECTION DESIGN AND TRAFFIC
MANAGEMENT**

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ABSTRACT

The majority of current geometric and traffic control design standards are based on design principles, vehicle characteristics and human physiological attributes that originate from the 1960s. During the past 30 years significant changes have occurred in the vehicle characteristics and fleet composition. Significant changes have also occurred in the composition of the driver population to include an increasingly larger proportion of older drivers, whose physical characteristics differ from those of the test populations used to set the design standards back in the 1960s. Studies indicate that older drivers differ from middle-aged and younger drivers in terms of the type and amount of driving they do, as well as characteristics of the accidents in which older drivers are more likely to be involved. This paper reviews the physiological characteristics of the older driver that are thought to contribute to motor-vehicle accidents, and to intersections accidents in particular. The expected growth in the proportion of drivers having these characteristics may warrant changes to current design standards and/or management policies. Recognising that changes in design standards and management policies may have both positive and negative effects on overall traffic flow characteristics, a method for modelling proposed changes in design and control standards for the purpose of traffic management is discussed.

1 INTRODUCTION

Current demographics in Canada and the US indicate that the number of elderly persons, as a proportion of the total population, is increasing and is expected to continue to increase over the next 30 years. Data from Statistics Canada, illustrated in Figure 1, indicate that by the year 2030, over 20 percent of the population in Canada is expected to be over the age of 65.

As the population ages, it is expected that the elderly will drive their personal automobiles more frequently and for longer distances, and will continue to do so until an older age than the elderly have done in the past. This projection includes not only the older driver (65 years and older), but also the very old driver (those drivers 80 years of age and older). Analysis of a population-based health survey carried out in Ontario in 1990 indicates that almost 38% of the population aged 80 or older continue to drive a motor vehicle at least once a year (Chipman et al, 1999). Actual and projected data from the Nationwide Personal Transportation Survey conducted in the US in 1990 indicate that the average annual kilometres of travel by those 65 years of age or older will increase from approximately 50% of the annual kilometres travelled by those less than 65 years of age in 1993, to approach 80% by the year 2030. This trend should give rise for concern. When accident rates are adjusted for driving exposure, older drivers have been found to have significantly higher crash rates than those found for middle-aged (25-59 year old) drivers (Chipman et al, 1993). Without attention to countermeasures directed at improving the driving safety of the older driver, accident rates for the elderly are likely to increase rather than decrease.

These significant projected changes in the amount of automobile travel by the elderly result from a number of interacting factors, including;

- Increased proportion of the elderly in the population.

- The cohort representing these drivers has grown during a time of unparalleled growth in automobile ownership and use. These individuals are habituated to the use of their automobiles to a degree not experienced by any previous cohorts.
- In previous cohorts, elderly women were observed to drive very little, relative to younger women and to younger and older men. However, as is illustrated in Figure 2, there is evidence that this trend is changing, and that these differences in driving participation rates between older women and older men are disappearing.

2 DIFFERENCES BETWEEN OLDER AND YOUNGER DRIVERS

In order for traffic engineers to begin to identify appropriate countermeasures, it is important to understand the differences between older drivers and the middle-aged drivers (25-64 year olds) who are considered to be the "safest" in terms of accident rates (McGwin & Brown, 1999). Two factors are of particular importance: the characteristics of the accidents in which older drivers tend to be involved, and the characteristics of the older drivers that may be contributing to those collisions.

2.1 Accident Characteristics

A review of the literature reveals similar trends when older drivers are compared to the middle-aged drivers (Cooper, 1990; Hakamies-Blomqvist, 1993; McGwin and Brown, 1999;). A summary of these trends are listed below:

- Older drivers are more likely to experience crashes at intersections, during daylight hours, and under good weather conditions.
- Older drivers are more likely to be making turns when the crash occurs, particularly left-hand turns.
- Older drivers are more likely to be identified in police reports as being "at-fault". The older driver is more likely to report that he/she did not see the other vehicle or that detection of the other vehicle was so late that there was not sufficient time to avoid the collision (Hakamies-Blomqvist, 1993).
- Alcohol and excessive speed is less likely to be a factor in crashes involving older drivers, factors which are seen more prevalently in younger drivers (McGwin & Brown, 1999).
- 80% of crashes for both older and middle-aged drivers are experienced within 25 miles of the driver's residence (McGwin & Brown, 1999).

2.2 Accident Severity

A further issue related to older drivers is the differences in the consequences of their collisions relative to younger drivers. In particular, driver fatality rate data from the US (Figure 3) indicate that the oldest and youngest drivers are more often involved in traffic fatalities than the members of the other age groups. A study by Hauer (1988) examined the location of traffic incidents resulting in injury or death and stratified the results by age of the driver. Hauer found that older drivers (those aged 65 years and older) are 25% more likely to be injured in a collision at an

intersection than younger drivers, and 105% more likely to experience a fatal incident at an intersection than younger drivers.

The higher rate of fatalities for the older drivers may be explained in part by the nature of the intersection accidents. In collisions involving turning vehicles, the point of impact on the car of the older driver is likely to occur at the front quarter or side of the vehicle. Such impacts are more likely to result in serious injury for the older driver (Viano et al, 1990). As well, Evans (1988) suggests that many older drivers are physically less robust than the younger counterparts and thus are more likely to suffer severe to fatal injuries in such collisions. While physical frailness may help to explain why older drivers might be more likely to succumb to their injuries, it does not explain why those drivers are more likely to be involved in intersection accidents in the first place. To gain a better understanding of why older drivers may be at more risk at intersections, one needs to consider the physical and psychophysical characteristics of the older driver.

3 PHYSIOLOGICAL CHARACTERISTICS OF OLDER DRIVERS

3.1 Turning At Intersections

Intersections may be signalised or non-signalised, single lanes, or multi-lanes, with marked turning lanes or without. Regardless of the geometry and specific traffic control, traversing an intersection demands similar skills of all drivers. The driver must be able to quickly assess the context of the intersection (whether turns are permitted; whether turning lanes are designated; whether there are traffic signs or controls to govern right of way). This assessment requires visual processing to detect the features of the intersection and traffic environment and to read any signs, symbols, or signals. The driver must also use higher-level cognitive processing to interpret those perceptions and decide upon a plan for manoeuvring through the intersection. With the presence of oncoming or turning traffic, or crossing pedestrians, the driver must monitor the environment to gauge how quickly the other objects are approaching, and to select an appropriate gap that will allow the driver to safely cross through the intersection.

In making a left-turn, a driver must try to estimate the approach speed and closing distance of other objects in the environment (other vehicles, pedestrians, etc.) to establish safe "gaps" in traffic through which to make the turn. This information needs to be perceived, interpreted, compared in working memory against the driver's knowledge of adequate gaps, and decided upon in a timely manner. Once the decision has been made to initiate the action the driver must respond physically, all the while being prepared to exercise crash avoidance by stopping the car if necessary to wait for another appropriate gap or by accelerating the car through the turn to avoid collision with an oncoming vehicle

It is generally accepted that visual, perceptual, and cognitive functions decline with age, and that such impairments can contribute to a decline in driving abilities (Szlyk, Seiple, & Viana, 1995; TRB, 1988). Such declines may contribute to but not necessarily cause motor vehicle accidents.

3.2 Visual Perception

Good visual perception and attention to the characteristics of the traffic environment are important if a driver of any age is to integrate the information necessary for safely traversing an intersection. Cognitive deficits as well as deficits in older drivers' visual information processing

ability, as measured by Useful Field of View (UFOV), have been found to correlate with higher crash involvement. A study by Owsley et al (1991) found older drivers who failed the UFOV test to be 4 times more likely to be involved in a crash and 16 times more likely to be involved in an intersection crash. Loss in peripheral sensitivity is generally thought to contribute to attentional deficits and consequently to deficits in visual search (Fisk & Rogers, 1997). Given that one's peripheral vision is responsible for detecting movement within the visual field, this may have an impact on whether the older driver is able to adequately perceive and interpret the actions of approaching objects within the driving environment. If the driver does not detect the approaching object in the first place, then it would be impossible for that driver to reliably identify suitable gaps for making a left turn. Furthermore, if the driver misses cues in the environment, then he/she may not be able to accurately assess who has right-of-way.

3.3 Head Turning to Check for Vehicles

A driver contemplating making a turn at an intersection must check for oncoming traffic and potential collision paths with other objects. In making a permissive left-turn the driver must check to the left for pedestrians and bicyclists that may be crossing the roadway. In making a right-hand turn, the driver must check to the left for traffic approaching from the other stream, and to the right for pedestrians and cyclists. This monitoring of the traffic environment requires the driver to turn the head to conduct the appropriate visual search. Besides decrements in visual acuity and field of view, older adults often experience restriction in their ability to turn their head. In driving, such restrictions have been found to compromise the driver's UFOV and visual search. Such restrictions could have implications for the geometric design of traffic intersections.

Drivers with restricted field of view can often compensate by using a series of quick, effective head and eye movements to scan the traffic environment. Unfortunately, many older drivers suffer from restricted head movement due to arthritis, lower muscle tone, or neurological disorders (Isler, et al. 1991). Such restrictions of movement further compromise the visual search that the older driver can perform at an intersection. Isler and his colleagues (1991) tested 80 drivers across 4 age groups (under 30 years; 40-59 years; 60-69 years; and 70 years and over) for visual acuity, depth perception, horizontal peripheral vision, and maximum head movements. The youngest age group was found to have maximum head movement of more than 70°, while the majority of drivers over 60 years of age had maximum head movements of much less than 70°. Based on their findings, Isler et al (1991, p. 797) predicted that most older drivers at the decision point of a T-intersection would have difficulty bringing vehicles beyond 50 m into focus in their central vision without having to make additional eye, head, and upper torso movements.

3.4 Comprehending Who has the Right-of-Way

McGwin and Brown (1999) analysed all police-reported traffic crashes occurring in the state of Alabama during 1996. Among crash-responsible drivers, almost 30% of the accidents attributed to older drivers were classified as "failure to yield right-of-way". An older driver's failure to yield is often attributed to their decline in visual search and cognitive processing. Staplin and Fisk (1991) proposed that older drivers would benefit from having advance information regarding right-of-way prior to reaching the intersection. To test their hypothesis, drivers performed a laboratory-based tracking task to simulate driving and were shown a series of advanced sign-plus-signal information. Based on the advanced information, the driver was to decide whether he/she would have the right-of-way to make a left turn at the intersection. While

the performances did not differ significantly between the older and younger drivers, Staplin and Fisk recommend designs for advance right-of-way information be sufficiently conspicuous and legible to accommodate for an older driver's information processing needs.

3.5 Determining the Available and Required Gap Size

In order to determine appropriate gap size the driver must be able to adequately judge the speed and closing distance of the approaching object. The judgement of speed and distance has been shown to be particularly problematic for older drivers as they tend to wait longer than younger drivers for a suitable gap and still tend to underestimate the size of the gap needed for them to turn (Hancock et al, 1991). While this gap assessment is going on, the driver must compare the current dynamic situation with their working knowledge of what constitutes an adequate gap for traversing the intersection before making a decision.

Guerrier et al (1999) conducted a study to assess the contribution of field dependence, visual search skill, working memory, and reaction time to left turn performance. The focus was on the decision times and gap choices made by a sample of female drivers. The researchers focused on female drivers as older female drivers have been found to be even more at risk of an accident at intersections than younger female or male drivers. Guerrier and colleagues found that individuals with larger working memory capacity took longer to make a decision but consequently identified larger gaps as being appropriate for turns. This supports similar research reported by Lerner (1994). Lerner and his colleagues found that older drivers require longer gaps than do younger drivers. He reports that the gap duration accepted 50% of the time by younger drivers was 6.74s, and 7.85s by the older drivers. Unfortunately, it is not clear from the summary provided whether this gap time holds over all intersection types or only for stop-controlled intersections.

In a study carried out in Japan, the in-car driving behaviours of older drivers were compared with those of young drivers at intersections (Keskinen, et al, 1998). They found that the attention behaviours, as measured by a movement of the head in the direction of a visual search, were similar for older and younger drivers. However, the age groups showed differences in acceleration through the manoeuvre, with younger drivers accelerating more quickly and consequently completing the turns in less time. It is possible that older drivers underestimate the time it will take to accelerate their vehicle and as a result choose gaps in traffic that are not sufficiently long to allow them to complete the turn. Hakimes-Blomqvist (1993) suggests that older drivers may not readily perceive a change in their ability to quickly accelerate which may contribute to their underestimation available turning time.

3.6 Driving Compensation

In a simulator-based study, Szlyk et al (1995) found that older drivers as well as drivers with compromised vision were more likely to reduce their risk-taking (e.g. drive more slowly than younger drivers, not pass or change lanes in traffic). Other studies have also found that older drivers are likely to compensate for ageing effects by restricting their driving. For example, older drivers have been found to make less trips than younger drivers thereby reducing their overall risk of conflict (Chipman et al, 1993), tend to avoid driving at night due to the debilitating effects of glare experienced by older eyes (Morgan and King, 1995) and tend to avoid driving during rush hour when gaps in traffic are reduced and conflicts involving following too closely or merging traffic are more prevalent for all age groups (Kline et al, 1992). According to Burns (1999) older drivers are less likely to drive unfamiliar routes than younger drivers.

Consequently, they are more likely to continue to take "local" trips, which unlike highway driving, is more likely to increase their exposure to intersections.

4 INTERSECTION COUNTERMEASURES

Given that older drivers will continue to drive with increasing numbers, and that traversing intersections will be inevitable, it is important that countermeasures that accommodate for ageing drivers be considered. Appropriate interventions might focus on helping older drivers readily identify when they have right-of-way, and when a gap in traffic is appropriate for making a turn given their particular level of driving skill. Larger cues at stop-controlled intersections might help older drivers determine right-of-way. At signalised intersections, protected left turns (e.g. left turn on left arrow only) help diminish the number of stimuli to which the older driver needs to attend and eliminates the need for gap decisions. As well, attention to the geometric design of the intersection could provide increased sight lines (e.g. elimination of obstructions such as road level obstacles, overhead wires and trees, and excessive signage at intersection corners). Increased sight lines could provide more advanced information regarding approaching traffic and allow more time for the older driver to process information and to react appropriately. In the future, advanced technological solutions might be considered to aid the older driver in crash avoidance. For example, an in-vehicle system that would cue the driver to appropriate gaps between oncoming vehicles and pedestrians might assist older drivers at those intersections that do not have protected left-turn phases. Of course, besides the obvious implementation problems associated with such high-tech solutions, there would be a number of human factors/information processing issues associated with introducing additional cues or interfaces into the vehicle and subsequently the driving task. It is important that traffic engineers be aware that the most appropriate countermeasures should be of value to all drivers (not just older drivers), must be implemented at reasonable cost, and should not make the driving task harder for the older driver.

5 A FRAMEWORK FOR ASSESSING THE IMPACTS OF CHANGES IN DESIGN GUIDELINES AND CONTROL STRATEGIES

The findings discussed in the previous sections demonstrate that the issue of older drivers is of significance for three main reasons. First, the profile of the population in Canada and the US is changing, so that the proportion of the elderly is increasing. Second, the proportion of older drivers and the amount that these older drivers travel are increasing. Third, the elderly experience specific physiological changes as they age, and some of these changes have been shown to have a direct impact on driving capabilities.

The impact of implementing a change in either a design guideline or in a control strategy can be evaluated by examining the impact in isolation or in combination. Isolated impacts are those that directly and immediately result from the implemented change. For example, if the letters or symbol sizes on supplemental signs (e.g. no left-turns from 4-6pm) were increased to accommodate vision of 20/80 instead of 20/40 then most drivers would be able to read these signs from further upstream and consequently have a longer period of time in which to make an appropriate response. Combined impacts include the direct impacts but also include the secondary impacts that result from the changes implemented. For example, in recognition of the increased difficulties that older drivers have in executing permissive left-turns, a policy decision might be made to convert 2-phase signals to 4-phase signals with protected left-turn phases for

all approaches. Analysing the impacts in isolation would indicate a reduction in the probability of collisions that result from drivers attempting to use gaps that are too small. However, if the analysis considered the combined impacts, it would also consider the potential that the increased lost time (due to the additional phases) would increase delay and compromise the provision of adequate capacity. Furthermore, the impact that the change in phasing has on the driver population as a whole (not just older drivers) should be examined.

Figure 4 illustrates the components and linkages in the human-vehicle-roadway system. The appropriate framework for modelling this system depends a great deal on the purpose for which the system is to be modelled. If the intent is to examine the influence that enforcement has on driver behaviour, then a detailed sub-model must be created that links the level and type of enforcement with changes in driver behaviour. However, if the intent is to examine the influence that driver aids have on safety, then the effect of enforcement is much less important and does not need to be modelled explicitly.

Within the context of examining the impact of older drivers, at least two elements of the human - vehicle - roadway system need to be modelled in detail. The first element consists of the driver attributes, and specifically those attributes that are different between older and younger drivers, such as driving experience, visual acuity, etc. The second element is the roadway environment. For this element, two considerations determine the attributes of the roadway environment that must be modelled. First, those attributes of the roadway environment that have a significant impact on older driver behaviour must be modelled (e.g. intersection geometry; night time lighting levels; permissive left-turn phases; availability of gaps for left turns and merges; pedestrian flows, etc.). Second, those elements of the roadway environment that are affected by changes to the design standards or management policies must be modelled (e.g. sign lettering and reflectivity; signal phasing; intersection geometry, etc.).

The framework presented in Figure 4 is generic in nature, in that it can be said to apply to many existing microscopic traffic simulation models. The unique nature of each of these models comes from the degree to which each element in Figure 4 is represented in the model. A review of existing traffic simulation models (Bernauer, et al, 1997) indicates that very few models currently represent the required elements of the driver-vehicle-roadway environment with the level of detail necessary to adequately evaluate the impact on older drivers of a range of changes in design standards and management strategies. Some researchers have developed statistical models (Garber and Srinivasan, 1991), however, these models do not explicitly account for driver behaviour or driver characteristics, and cannot be used to evaluate the impact of potential countermeasures, unless the countermeasure is represented as an independent variable within the model. This implies that if these impacts are to be modelled, then either an existing simulation model must be modified and enhanced or a new model must be created. The next section discusses the model elements that would be required to adequately evaluate changes in intersection control policies and/or intersection design standards on older drivers.

6 MODELLING OLDER DRIVERS AT INTERSECTIONS

The modelling of traffic and driver behaviour at intersections can be examined on the basis of the sequence of events that occur and the decisions that drivers (all drivers, not just older drivers) must make when traversing an intersection approach link and the intersection itself. For the

purpose of modelling, the process can be segmented into three distinct phases, namely *Approach*, *Navigation*, and *Turning Movement Execution*.

The *Approach* phase is associated with perceiving the context of the intersection and the type of traffic control, assessing who has right-of-way, estimating how far the intersection is from the vehicle's current position, and deciding whether to slow the vehicle or to proceed.

The *Navigation* phase is associated with wayfinding. The intersection provides route options and consequently a decision on the appropriate turning movement must be made. The challenge posed by the *Navigation* manoeuvre depends a great deal on the *a priori* knowledge of the driver. A driver's knowledge or experience can generally be identified with one of the three following categories.

1. The driver is familiar with the road network and is familiar with the desired route. This driver knows what turning movement is to be chosen at the intersection, and knows what intersection is being approached without needing to read street name signs, or supplementary signs that might indicate permissible turns.
2. The driver is familiar with the desired route, but not familiar with the road network. This driver knows what turning movement is to be chosen at the intersection, but does not know what intersection is being approached until he/she is able to locate and read posted street name signs.
3. The driver is not familiar with the desired route and is not familiar with the road network. This driver does not know what turning movement is to be chosen at the intersection until he/she is able to locate and read posted direction signs, and also does not know what intersection is being approached until he/she is able to locate and read posted street name signs.

Once a turning movement is selected, the driver must also identify the lane(s) that permit this movement, and if not already in this lane, must make the appropriate lane changes in order to move into the appropriate lane. These activities are also part of the *Navigation* phase.

The last phase, *Turning Movement Execution*, consists of the driver completing the selected turning movement. In general three possible turning movements exist, namely left turn, right turn, and straight through. Each of these movements can be executed under different conditions, depending on the traffic control in place, and consequently requires different driver behaviour. For example, a left-turn manoeuvre can be executed at a signalised intersection under a protected phase, a permitted phase, or during the amber phase; from a stop controlled minor street to a major street; from an uncontrolled major street to a minor street; or at an all-way stop controlled intersection. At the outset of this phase, the driver must identify an appropriate gap in traffic that will allow the safe completion of the desired manoeuvre.

The modelling of each of these three phases - *Approach*, *Navigation*, and *Turning Movement Execution*, pose different challenges to the driver, and different characteristics of the driver, vehicle, and environment are important factors in determining driver behaviour. Table 1 presents a detailed breakdown of the driver behaviours associated with each of the three phases, and identifies a number of factors that are expected to play a significant role in determining the outcome of those driver behaviours. The identification of the elements in Table 1 is a necessary first step in the development of model for evaluating the impact of changes in intersection design or control on drivers and older drivers in particular. Based on the existing road safety literature, it

is clear that appropriate gap identification is critical for the safe traversing of intersections by the older driver. For this reason, the modelling of driver behaviour at intersections will focus on the sub-component related to appropriate gap identification.

7 DEVELOPING A SUB-MODEL FOR GAP IDENTIFICATION AND SELECTION FOR PERMISSIVE LEFT TURN MOVEMENTS

As noted above, the execution of a permissive left turn movement is a particularly important one in the study of older drivers, since empirical data indicate that older drivers find this movement especially difficult. For the purposes of traffic management, it is important to understand the challenges that are faced when trying to model drivers executing this movement in a way that permits differentiation between older and younger drivers.

As noted in Table 1, the permissive left-turn movement consists of a number of driver tasks and decisions. This sub-model is comprised of three components, namely the drivers' ability to identify gaps, the drivers' estimate of the gap duration, and the drivers' assessment of whether the gap duration meets or exceeds the required gap size. At this point in the development of the model, the issue of comprehension of the traffic control, the identification of pedestrian conflicts, or the task of tracking the vehicle through the intersection is beyond the scope of consideration.

It must be noted that the intent of this section is to illustrate the necessary elements and inherent complexities associated with modelling driver behaviour at this level. The proposed models and sub-models should not be viewed as finished products, but rather, the first building blocks towards a complete modelling tool.

7.1 Identification of Gaps

The identification of gaps depends primarily on the line of sight available to the driver and the driver's visual acuity. Line-of-sight constraints, which impact all drivers regardless of age, limit drivers' ability to view the opposing traffic stream. Typical intersection geometry places opposing left-turn bays opposite of each other, with the result that vehicles in the opposing left-turn bay can restrict the driver's view of the opposing traffic and limit the distance over which gaps can be identified (Figure 5).

The modelling of the line-of-sight component requires accurate data on the geometry of the intersection, a mechanism for estimating the lateral position of the vehicle in the left-turn bay, the probability that there will be a vehicle in the opposing left-turn bay, and an estimate of the lateral position of the opposing vehicle. These data can then be used to determine the maximum distance upstream of the stop line that the driver of the left-turning vehicle is likely to be able to see. This distance is also the maximum gap size (distance) that the driver can visually confirm. To extend these considerations beyond the "typical" driver, one must also adjust sight-lines based on expected seated stature and UVOF of the older driver. At present, data on these two characteristics are limited.

7.2 Estimating Gap Duration

As reported in previous sections of this paper, a number of reports in the literature (FHWA, 1998; Fisk and Rogers, 1997) have indicated that older drivers have difficulty with estimating gap duration as a result of decreased depth perception (error in estimating gap length) and

especially decreased motion perception (error in estimating the speed of the on-coming vehicle). The challenge is to quantify the accuracy of drivers' ability to estimate gap duration as a function of driver age. While some laboratory and field based studies have been carried out (e.g. Guerrier et al, 1999), further study is still needed if a countermeasure other than a protected left-turn signal phase is to be used to help older drivers more accurately identify acceptable gaps in traffic at intersections.

7.3 Deciding on Acceptable Gaps

The last component to be modelled is the driver's decision as to whether or not an identified gap meets or exceeds the driver's required minimum gap size. Previous studies have shown that the minimum gap duration drivers are willing to accept is a function of the turning movement and the delay that driver has already experienced at the intersection (Velan, 1997). It is also acknowledged that there is significant variation in the minimum gap size drivers are willing to accept, even for similar geometric and traffic conditions. Very little evidence has been reported that indicates that the critical gap duration is also a function of driver age, however, this lack of evidence may be a reflection of the difficulty in obtaining such data, rather than an indication that differences do not exist.

Once these three model components are constructed and implemented within a simulation model, measures of performance, including delay, queue length, saturation flow rate, etc., can be estimated as a function of the proportion of older drivers in the left-turn traffic stream, the opposing flow rate and arrival pattern, signal timing plans, and intersection geometry.

8 SUMMARY

This paper has described and demonstrated three important issues:

First, the characteristics of the population of drivers are changing, and will continue to change over the next 30 years. Specifically, the driver population will include a greater proportion of older drivers (those 65 year of age and older) and very old drivers (those 80 years of age and older).

Second, older drivers have unique physical and physiological characteristics that influence their driving behaviour, and may be associated with the higher accident rates experienced by older drivers.

Third, an appropriate mechanism is required to evaluate the impacts of potential countermeasures. This mechanism must be responsive to those factors that differentiate between older and younger drivers, and must provide measures of performance that are useful for traffic management decisions.

It must be noted that while the countermeasures that are likely to be considered for evaluation will be designed to assist primarily the older driver, the evaluation of these countermeasures must consider their impact on the entire driver population.

Towards this end, this paper has reviewed the characteristics of older drivers that appear to have a significant influence on driving performance and has described a sub-model for reflecting the process of gap identification and selection. This sub-model could be used to form the basis of an evaluation tool that would permit the assessment of potential countermeasures.

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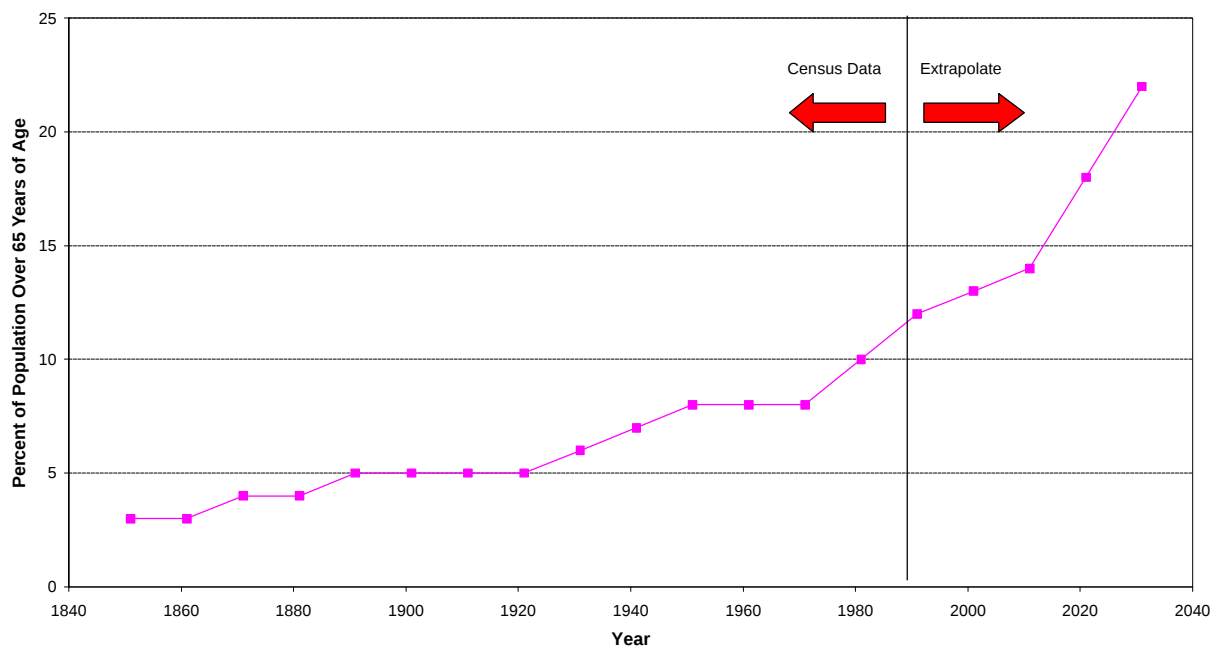


Figure 1: Actual and projected proportion of the Canadian population over 65 years of age (Source: Statistics Canada, 1994)

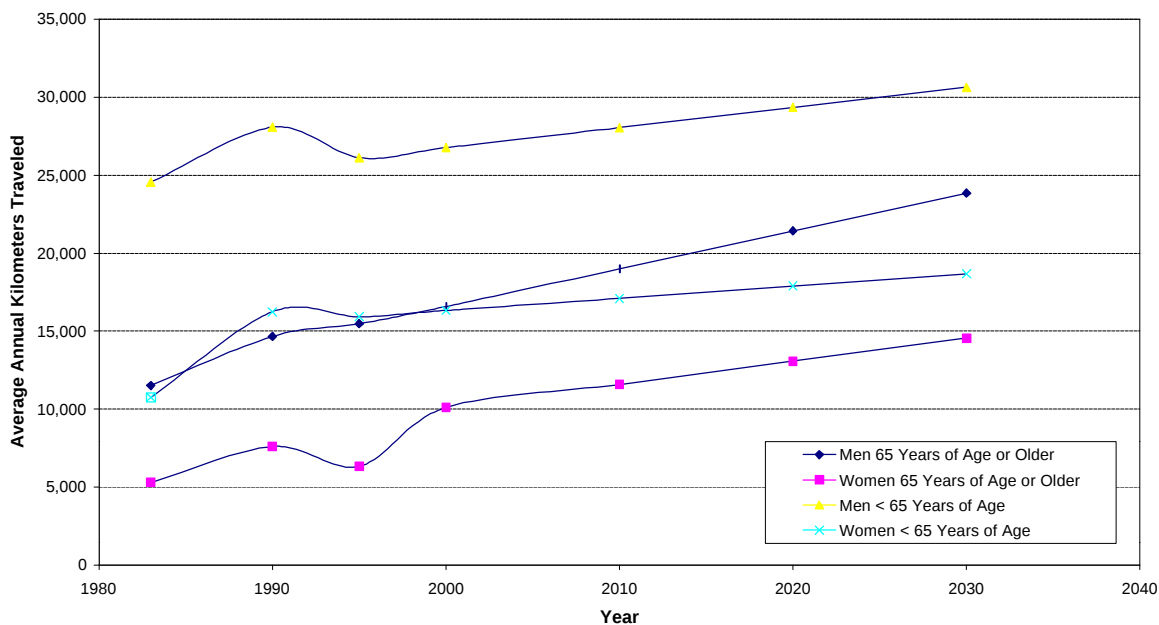


Figure 2: Actual and projected average annual kilometres driven in the US (Source: Hu et al, 1993; Burkhardt and McGavock, 1999)

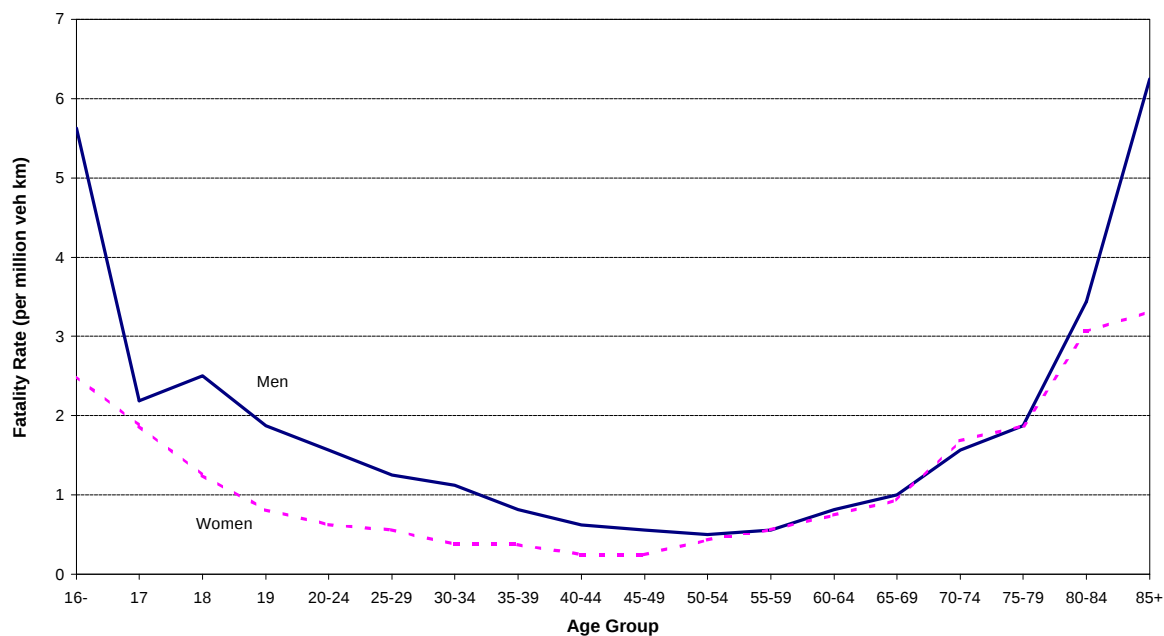


Figure 3: Fatality rate as a function of age group
(Source: Adapted from Burkhardt and McGavock, 1999)

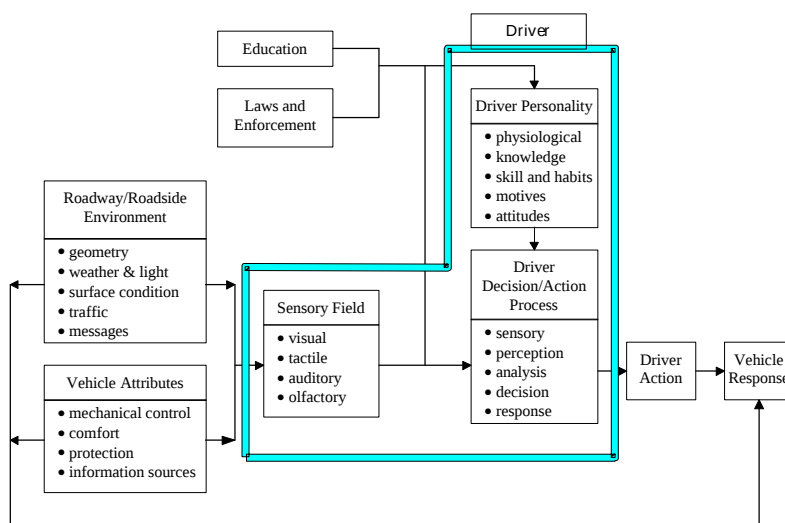


Figure 4: Human - Vehicle- Roadway Environment (Source: Adapted from FHWA, 1980)

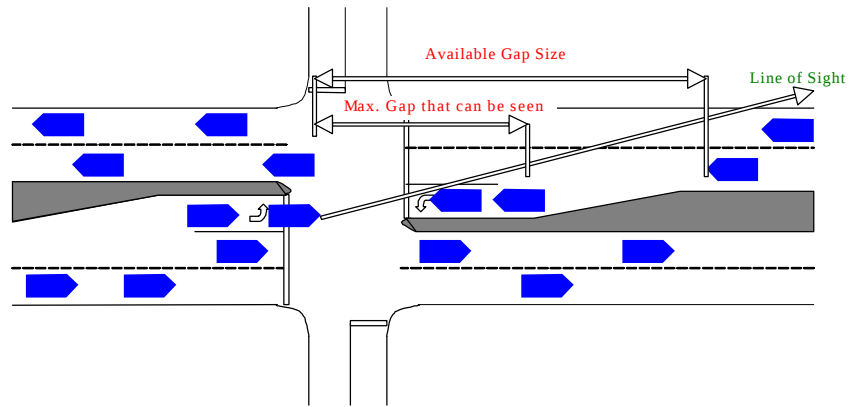


Figure 5: Illustration of line of sight restrictions on identifying gaps in opposing traffic stream

Table 1: Event sequence for modelling drivers traversing signalised intersections

Manoeuvre	Element of Driving Sequence	Significant Factors
<i>Approach</i>	See/perceive intersection and type of traffic control	Visual acuity, lighting, line of sight
	Determine who has right-of-way	Driving experience, cognitive processing
	Estimate distance to intersection	Depth perception
	Decide on action as a function of traffic control and understanding of who has current right-of-way:	Driving experience, aggressiveness, cognitive processing
<i>Navigation</i>	Locate and read street name/direction signs	Visual acuity, lighting, placement and size of signs, knowledge of the network
	Decide on desired turning movement	Cognitive processing, knowledge of route
	Identify lane(s) from which desired turning movement can be made	Cognitive processing, knowledge of route, visual acuity, comprehension of lane markings/signs
	If not already in appropriate lane, initiate a lane change to move to an appropriate lane.	Time available to make manoeuvre, availability of suitable gaps, time required to make manoeuvre (may be a function of peripheral vision, upper body flexibility, cognitive processing)
<i>Turning Movement Execution</i>	Identify intersection traffic control (e.g. signal, stop sign, yield, etc.)	Driving experience, knowledge
	Determine who has current right-of-way	Visual acuity, lighting, signs, driving experience, knowledge, cognitive processing
	If driver is permitted to proceed, but must yield right-of-way to other traffic streams, the driver must identify gaps in opposing traffic stream	Visual acuity, line of sight
	Estimate gap duration	Depth perception, motion perception, line of sight
	Estimate required gap size	Driving experience, intersection geometry
	Perceive conflicting pedestrian stream and identify suitable gaps	Visual acuity, cone of vision, upper body flexibility, cognitive processing, intersection geometry
	Control steering (track) of vehicle through intersection	Driving experience, intersection geometry, pavement markings and signing, lighting

