DISTANCE BASED VEHICLE INSURANCE: ACTUARIAL AND PLANNING ISSUES

by

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B.A. (Hon), University of British Columbia, 2005

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARTS

in

The Faculty of Graduate Studies

(Community and Regional Planning)

THE UNIVERSITY OF BRITISH COLUMBIA

April 2008

ABSTRACT

Distance based vehicle insurance (sometimes know as “Pay as you drive,” “Pay by the mile” or “Pay per-km” insurance) has long been advocated by transportation planners as a transportation demand management (TDM) strategy. In addition to reducing congestion and greenhouse gas emissions, it also has the potential to meet a number of planning goals, such as health and equity improvements. Despite the wide interest in and predicted benefits of distance based insurance, there is little consensus on the detailed design of a system that could be implemented. Five main distance based pricing schemes have been proposed: a flat per-km rate, temporal or “time of day” pricing, road-type pricing, demographic pricing and “differential” pricing, which prices low mileages at a higher per-km rate. Each of these systems treats risk differently and thus results in different cross-subsidies between drivers. The proposal’s design thus has implications for an insurance system’s fairness and equity.

This report examines the distribution of crash risk across time, across space, and across the different demographic groups. It then compares the current annual insurance system’s treatment of risk with that of various proposals for distance based insurance. It evaluates each proposal, considering its treatment of risk and its potential for increasing fairness and equity of costs and of mobility. It also examines each proposal’s other impacts, such as effectiveness in maintaining privacy and in reducing health impacts, greenhouse gas emissions and congestion. The recommended model is a flat per-km rate. Each driver would pay the same rate for every kilometer driven, regardless of time or place. However, individual drivers’ per-km rates would vary, depending on current insurance rating factors, such as residential location, type of car and driving record.

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LIST OF ABBREVIATIONS

GPS	**Global Positioning System**
GVRD	**Greater Vancouver Regional District**
LRSP	**Livable Regional Strategic Plan**
TDM	**Transportation Demand Management**
TSM	**Transportation Supply Management**

ACKNOWLEDGEMENTS

I would like to thank my thesis committee, Larry Frank, Lorne Whitehead and Todd Litman for taking this on as both an academic and a practical project. In addition, I would like to acknowledge Tristan Laing for being relentless critic, in the best sense, of this project. Finally, thank you to Ignacio Couturier for a thoughtful and thorough editor and for providing me with an unnamable amount of support over the last year.

1.1 Introduction to distance based insurance

Growing concern about climate change in British Columbia has created great public interest in methods of reducing greenhouse gas emissions. Transportation policies, such as road pricing and emissions standards, are among some of the most debated issues. Despite this, some of the most promising possible transportation initiatives have rarely been discussed. One of these is distance based vehicle insurance. Although distance based vehicle insurance exists in limited forms in a few places in America, Europe, Asia and elsewhere in Canada, it has yet to receive political support in most places, and British Columbia is no exception. However, distance based insurance is supported by a growing coalition of B.C. citizens, transportation advocates and local governments. Amongst other possible strategies for reducing vehicle use; distance based insurance may well become seen as a preferred mechanism.

Distance based vehicle insurance, which is sometimes called 'Pay as you drive' or 'Pay as you go' insurance, is a way of pricing insurance based on how much the vehicle is driven during the policy term. In the 'Pay as you drive' model, which will be examined in this report, individual drivers would continue to buy insurance from an insurance company, but under a revised pricing system. This distinguishes it from 'Pay at the pump' schemes, which involve eliminating insurance premiums and replacing them with revenue from a gasoline levy.

Distance based insurance has been advocated, since the 1960s, by individuals ranging from economists to the National Organization of Women. Although the reasons for its advocacy are wide ranging, transportation planners and researchers have often framed it primarily as a transportation demand management (TDM) tool. In this context, distance based insurance is seen as a mechanism for reducing traffic and parking congestion and for reducing vehicle emissions. Despite this focus, distance based insurance also has the potential to address other public goals.

The rationale behind distance based insurance is the desire to shift the costs of driving from fixed to variable or marginal costs. It is well established that, when making travel decisions, individuals weigh variable or 'out of pocket' costs, such as gasoline, tolls and transit fares more heavily than sunk costs such as vehicle ownership and insurance. Changes in variable costs "have a strong influence on travel decision-making" (Wachs, 1991). Therefore, increasing variable costs have has significant potential to reduce auto use.

Currently, insurance is a fixed cost of driving as drivers pay an annual or pro-rated semi-annual fee, which is relatively insensitive to the distance they drive. Current rate classes do incorporate mileage and vehicle usage (e.g. commuting). However, the difference in price between mileage categories is very small compared to the total cost of insurance. Furthermore, the current rate classes "are very broad and to a considerable extent are based on the unverified statements of the applicant" (Vickery 1968). This relatively flat-rate system does not encourage drivers to reduce their mileage and may even have the opposite effect to some degree as drivers attempt to "get their money's worth" on their insurance by driving more. Distance based insurance, in contrast, by offering a cost reduction for decreased mileage, incentivizes motorists to reduce their driving. Distance based insurance, unlike conventional annual systems, can offer cost savings even for small mileage reductions. Therefore, many drivers can potentially benefit from this system. Residents in neighbourhoods with many transportation choices may have the most opportunities to reduce trips. However, even in low-density, suburban neighbourhoods, where there are few transportation options, residents can save money by trip chaining and by forgoing low-value trips.

1.2 Report boundaries

1.2.1 Purpose

Although distance based insurance has long been advocated by transportation planners, little attention has been given to the precise design of a distance based pricing system. These details have been considered to be a simple matter and the responsibility of insurance companies rather than transportation planners. However, distance based pricing engenders several problems, including the difficulty of maintaining actuarial accuracy and revenue neutrality. In addition, some proponents of distance based insurance, particularly those in the insurance industry, have proposed combining distance based insurance with other pricing schemes, such as time of day and road type pricing. Such programmatic design considerations entail different social, environmental and economical impacts. This makes the design of a distance based pricing system a planning issue. While the detailed design of any pricing program must be done by individual insurance companies, this report will attempt to elucidate the general principles of a pricing system that would meet key public goals.

1.2 2 Geographic scope

This report addresses the potential use of distance based insurance as a means for meeting transportation demand management and other planning goals in the Lower Mainland Although distance based insurance could be implemented throughout British Columbia, its impact on rural areas will not be discussed. This is reasonable because insurance in British Columbia already has a rate structure that is dependent on location within the province. This is not because distance based insurance is not a desirable policy for the entire province, but because its exact impacts will differ in urban and rural areas. Because ICBC has a rate structure which is dependent on location within the province, distinct regions should be examined separately. As urban areas have more complex transportation and housing patterns, this report will address insurance pricing in the province's largest metropolitan region.

1.2.3 Insurance type

This report will address insurance pricing for non-commercial passenger vehicles. While a distance based program could also be implemented for commercial vehicles, it would raise different issues and require a different design. This analysis would fall outside the scope of a report of this length.

1.3 The planning context

1.3.1 Provincial and Metro Vancouver policies

Distance based insurance is one means of achieving various goals set by provincial, regional and local governments in British Columbia. These aims include environmental, public health, livability and transportation efficiency improvements. As described below, some levels of government have already identified distance based insurance as a tool for meeting these aims.

At the provincial level, the current government has recognized climate change as a major issue necessitating long-term financial commitments. Finance Minister Carol Taylor has stated that "[climate change] is an over-riding issue that won't be a one-budget issue."(Bermingham, 2007). This budgetary commitment supports an ambitious target: in its 2007 Throne Speech, the

BC government promised to "reduce B.C.'s greenhouse gas emissions by at least 33% below current levels by 2020." The throne speech also acknowledged that 40% of the province's greenhouse gas emissions are from the transportation sector. Because of this, any attempt to reduce provincial greenhouse gasses will need to address auto travel. Distance based vehicle insurance can play an important role in meeting the reduction targets.

At the regional level, Metro Vancouver (formerly the Greater Vancouver Regional District), in its 1999 Livable Region Strategic Plan (LRSP), supported increasing transportation choice as a strategy for increasing community livability and improving environmental protection. The plan identified transportation demand management as a "fundamental transportation requirement for achieving the goals and objectives of this Strategic Plan." It also committed to entering into "partnerships with Metro Vancouver member municipalities, local, provincial and federal governments and private organizations for the establishment of a regional capability to develop, coordinate, implement and monitor TDM strategies." While road and parking pricing are the most commonly discussed TMD measures, distance based insurance is also a viable TDM strategy.

More specifically, Metro Vancouver staff, in response to a City of Vancouver council resolution, have evaluated distance based insurance in relation to the LRSP. They found its "transportation demand management and emissions reduction benefits [...] compatible with the principles informing the Sustainable Region Initiative, strategies in Metro Vancouver's existing regional growth strategy, objectives and actions in the 1994 Air Quality Management Plan and the draft Clean Air Strategy" (Metro Vancouver 2005). They recommended that the Metro Vancouver endorse the City of Vancouver's request that the provincial government direct ICBC to implement distance based insurance. Distance based insurance, therefore, has been identified by both local and regional governments as being consistent with the region's planning goals.

1.3.2 Provincial and regional impacts

Distance based vehicle insurance offers a number of benefits, including:

- Reducing
    - Road and parking congestion
    - Greenhouse gas emissions

and

- Improving
    - Local air quality
    - Human health
    - Equity of access to mobility
    - Equity and fairness in paying for the costs of vehicle use.

These benefit's magnitude and character depend upon a number of factors, including geographic location and exact design of a distance based pricing system. Therefore, while an overview of impacts will follow immediately, a more detailed discussion of the implications of different pricing options is included in Section 3 of this report.

1.3.2.1 Environmental impacts

A distance based fee could be expected to have a measurable effect on both greenhouse gas emissions and ground level air pollution. Because the annual cost of insurance is quite high, converting it to a marginal cost would likely affect individuals' travel behaviour. For example, an average mileage motorist (18,000 – 20,000 km/year), driving a car of average fuel efficiency (22.4mpg) would pay approximately $0.82 per kilometer for fuel and pay $0.096 per kilometer for each kilometer driven (Canadian Automobile Association, 2007) (see Table 1). To put this in perspective, for this average driver, the insurance fee would be equivalent to an increase in fuel costs of 59 cents per litre. A high-risk driver might pay double this price for insurance. Even a price at the lower end of this spectrum would result in a shift of a few thousand dollars annually from fixed to variable costs for driving (see Table 1). More immediately, with the per-km cost of insurance being from equal to double that of fuel, it can be expected that some people will forgo some of their trips.

Table 1 Comparison of the variable costs of driving under annual and distance based vehicle insurance

	Annual Insurance		Distance Based Insurance	
Fixed Costs	**Per-km**	**Annual**	**Per-km**	**Annual**
Insurance	$0.096	$1,731.000	-	-
License & Registration	$0.007	$118.000	$0.007	$118.00
Depreciation	$0.236	$4,256.000	$0.236	$4,256.000
Finance Expense (Car loan)	$0.054	$975.000	$0.054	$975.000
Total	**$0.393**	**$7,080.00**	**$0.297**	**$5,349.000**
Variable Costs				
Insurance	-	-	$0.096	$1,731.000
Maintenance	$0.024	$424.800	$0.024	$424.800
Tires	$0.019	$338.400	$0.019	$338.400
Fuel	$0.082	$1476.00	$0.082	$1476.00
Total	**$0.125**	**$2,250.000**	**$0.221**	**$3,981.000**
Total	**$0.518**	**$9,330.000**	**$0.518**	**$9,330.000**

Source: Canadian Automobile Association (2007). Driving Costs. <http://www.caa.ca/documents/2007-04 27_DrivingCostsBrochure2007.pdf#search="your%20driving%20costs">.

Previous studies of drives' reactions to price increases allow an estimate of the order of magnitude of this impact. It is difficult to predict the exact effect of distance based insurance because it represents a somewhat unique type of price change. However, it has been consistently shown that total driving decreases in response to price increases. Marginal increases, such as fuel prices, have a greater effect on mileage than increases in sunk costs such as vehicle purchase prices or taxes. Distance based vehicle insurance, as a marginal cost, should have an effect similar to a fuel price increase, whose impact on mileage is well established. However, because it would be purchased monthly or annually, unlike fuel which is purchased frequently, consumers' reaction to it may be somewhat different. Distance based vehicle insurance would also effectively rebate drivers' previous insurance charges, thereby effectively increasing their income. This income increase may partially counteract the mileage reduction from marginal insurance costs. Despite these qualifications, distance based insurance will function in a similar way to a fuel price increase and therefore fuel price elasticities can be used as a rough proxy for distance based insurance's effect on driving.

Although fuel price elasticities vary, most are in the range of -0.2 (for example, see Johansson & Schipper, 1997). Assuming that fuel comprises about 15% of total vehicle costs, "a -0.2 elasticity of driving with respect to fuel price represents an elasticity of -1.3 with respect to total financial cost. This implies that if all user costs were converted into variable charges, each 1% increase in this charge would reduce driving by -1.3%" (Litman 2007). This impact is expressed in a different way in a recent overview of transportation elasticity research:

> If the real price of fuel rises by 10% and stays at that level, the result is a dynamic process of adjustment such that the following occur:
>
> > Volume of traffic will fall by roundly 1% within about a year, building up to a reduction of about 3% in the longer run (about 5 years or so).

A simple calculation from the above elasticity indicates that a 50-100% increase in fuel costs would decrease traffic volume by 5-10% in the short term and by 15-30% in the long terms.

The effect of a distance based insurance program, which adds a marginal cost to driving equivalent to a 50-100% increase in fuel costs could be somewhat larger than this number indicates. This is because the effect of a price increase is usually calculated as an arc elasticity (Litman 2007).. This method treats any price increase as number small increases which compound on one another, resulting in a higher effect than if the price and elasticity were simply multiplied. Regardless, the simplified calculation gives a general idea of the magnitude of the effect of a distance based insurance program.

This expectation has been confirmed in practice. For example, a pilot program by a Texas insurance company found that motorists on a Pay as You Drive (distance based) plan reduced their mileage by an average of 1,237 miles per year (Progressive County Mutual Insurance Company, 2007). Assuming the drivers in this pilot program were average distance drivers, this would be approximately a 9% reduction in mileage. Being a one year pilot program, this is indicative of a short-tem mileage reduction which would likely increase over the long term.

It is possible that the self-selected drivers in the Texas study were more likely than average drivers to reduce their driving. This means that a mandatory distance based insurance program might result in a smaller reduction in vehicle travel. However, there is no evidence that this is or is not the case. Furthermore, the Texas study was completed only six months after the launch of the pilot program. It is well known that the effect of transportation pricing is much greater in the long-term than in the short-term (Goodwin et al., 2004; Lee, Klein & Camus, 1999). For example, a review of studies on transportation elasticities estimated that long-term fuel price elasticities were two to three times greater than short-term elasticities (Goodwin et al., 2004) (The short-term is defined here as one year. The long-term is defined as one to ten years, but the greatest effects are generally seen in the first three to five years). If a similar pattern holds for marginal insurance pricing, then the long-term effects could be much greater than those observed in the Texas pilot. The mileage reduction might also be affected by a program's administrative structure. For example, if ICBC billed motorists monthly, they might have a greater awareness of their insurance costs. This could lead to a greater mileage reduction in comparison to an annually billed system.

While the effect of a vehicle mileage reduction on CO_2 emissions is quite direct, its impact on ground-level pollution is more complex. Depending on the type of pollutant, reductions in travel distance versus reduction in the numbers of trips taken may have different impacts on human health. For example, ozone produced by oxides of nitrogen and hydrocarbons covers a large area and is a function of both travel distance and trip frequency (Frank et al 2000). Alternatively, air toxics, small particulates, and carbon monoxide tend to be concentrated in small areas and more sensitive to cold engine starts and trip frequency. Overall, reducing mileage will reduce emissions, however, not necessarily exposure to air pollution in small areas. Pay as you drive insurance holds considerable promise in reducing miles driven and overall air pollution levels. Further research is therefore necessary to determine the exact magnitude and type of emissions reduction from a distance based insurance program. This would better allow a distance based insurance program to be compared to other transportation demand management strategies. Regardless of the magnitude, however, a distance based insurance program can be expected to reduce both greenhouse gases and ground-level air pollution.

1.3.2.2 Health impacts

1.3.2.2.1 Air Quality

Air pollution is a major health cost associated with vehicle use. The health impacts of air pollution include heart attack and stroke associated with exposure to small particulates (Pope et al 2000) and ozone (Bell, Jonathan, Samet & Dominici, 2004). As noted above, a major health impact of driving is air pollution. Cars produce numerous pollutants that have the potential for negative health consequences. In the Lower Mainland, two of the largest concerns are ground level ozone, which results from largely from the interaction of vehicle hydrocarbon emissions and sunlight, and particulate matter. Concern over the latter has grown in recent years as particulates have been shown to have both immediate and long-term effects on human health. Particulates' immediate effects include increased emergency room visits, exacerbation of chronic respiratory and cardiovascular diseases (Bell et al., 2004) and respiratory infection in children (Brauer et al., 2007). Long-term exposure is associated with decreased lung function, increases in lung cancer, cardiopulmonary mortality (Bell et al., 2004) and asthma and allergies (Brauer et al., 2007). These emissions impacts are not limited to pedestrians and residents of high-traffic areas; there is also evidence that particulate matter levels are very high inside running vehicles (Riediker, Williams, Devlin, Griggs & Bromberg et al., 2003). Therefore, vehicle drivers and passengers are, often unwittingly, putting themselves at risk from air pollution.

1.3.2.2.2 Collisions

Another obvious health benefit of distance based insurance would be crash reduction. As annual mileage is strongly correlated with accidents, reduced driving could reduce traffic injuries. These costs are significant. Injury costs constitute about 60% of ICBC's total annual claims costs of $2.5 billion (ICBC, 2005). Considering these large costs, even a small reduction in accidents would reduce costs to ICBC, to crash victims and to society at large.

The potential crash reduction resulting from road pricing programs is higher than the predicted mileage reduction might suggest. Most vehicle crashes involve either two vehicles colliding or one vehicle maneuvering to avoid another. Because of this, busier roads have more potential for collisions as "accident rates increase significantly with increasing traffic flows over the more significant ranges" (Vickery 1968). Although some of these crashes are less serious than those under less congested conditions, the total impact of higher traffic density outweighs that of the impact of higher speed in less congested conditions (Vickery 1986). Because of this, any driver's mileage reduction reduces not only their own crash risk, but also that of other road users. As a result, distance based insurance can reduce drivers' collision rates, regardless of whether they reduce their own mileage. This results in a phenomenon which has particularly relevance in British Columbia. The predicted average cost reduction in collision claims costs for individual drivers would be $31US under a distance based program. However, drivers' total collision cost reduction, including the costs individual drivers impose simply by being on the road, would be $58US (Edlin, 2003). Private insurance companies generally only realize the first cost savings, because they do not have to pay for their insurees contribution to traffic density and the resulting risk. ICBC, because it must cover the collision costs, would capture close to the full savings resulting from this policy.

1.3.2.2.3 Active Transportation

In addition to causing negative health impacts, their vehicle use decreases activities, such as walking, which have positive health impacts. The result is an increase in diseases related to obesity and sedentary lifestyles. Increased auto use is associated with higher obesity rates (Frank et al, 2004) and sedentary lifestyles (Wen et al., 2006), which result in several forms of chronic disease (Heart and Stroke Foundation of Canada, 2003). These chronic diseases, such as Type 2 diabetes, which require lifetime treatment, impose significant costs on the health care system. At least some of the vehicle trips eliminated through distance based insurance will likely be replaced by more active modes, such as walking and public transit. For all these reasons, distance based vehicle insurance can be expected to improve public health.

1.3.2.3 Congestion impacts

From an environmental and public health perspective, even a modest reduction in vehicles miles traveled (VMT) is desirable. However, for a pricing measure to succeed as a TDM strategy, it must reduce mileage during high-volume times on major roads. It is widely assumed that transportation pricing must be very precise in order to reduce congestion. For example, transportation economists often advocate road pricing that varies by time of day or even by a facility's minute-to-minute traffic volume. In comparison to these systems, distance based insurance may be a poor instrument for targeting congestion. However, the results of distance based insurance trials suggest otherwise. For example, one US insurance company conducted a trial of distance based insurance and measured its effect on motorists' annual mileages. Despite the fact that the fee structure did not include time-of-day pricing, the majority of the resulting vehicle mileage reduction was from peak hour trips (Progressive County Mutual, 2007). This result suggests that a distance based insurance program, by reducing peak hour trips, can help reduce traffic and parking congestion.

1.3.2.4 Equity impacts

Social equity is difficult to both define and measure. In terms of measurement, household income is the most commonly used indicator for evaluating equity impacts. This measurement has several limitations. First, it ignores significant non-income sources of wealth, such as material assets and non-earned income sources, including inheritances and gifts. In addition, the very concept of household creates distortions in the picture of wealth distribution. For example, a household income of $50,000 could represent a single person with an adequate salary or a struggling four-person household. Of course, measuring by individual income has its own limitations, as it does not reflect the expenses that can be shared among individuals in a multi-person household. Despite these measurement limitations, household income is the standard and, as of yet, best indicator for measuring equity.

Despite the widespread acceptance of household income as a measurement tool, it is often used without explicitly defining for what it is intended to be a proxy. For example, household income can reflect both life-cycle and socio-economic status. Either of these may be considered to have implications for equity. Wealth redistribution between different socio-economic groups is generally considered to be the main measure of a policy's impact on equity. Redistribution between age groups is less often considered to be an important equity goal. Theoretically, as individuals pass through different life stages, even if they are overcharged by a system at some point, their costs should even out over time. However, seniors' and students' discounts in North America are prevalent in North America. For example, there are often student and senior discount rates for swimming pools, theatres and public transit. In some jurisdictions, seniors also receive free college tuition. This indicates that there is a public preference for charging people lower fees at ages when their income is lowest. Therefore, both inter-class and inter-age distribution may be considered as equity issues.

By both of these measures, distance based auto insurance, in principle, is more equitable than standard insurance. It is well established that VMT increases with household income (Frank, et al, 2006; Ross & Dunning, 1997; Scottish Executive, 2005). There is also a similar relationship between household income and person miles traveled (Ross and Dunning 1997) and between per capita income and VMT (Holtzclaw, 2000). Therefore, this relationship is not an artifact of higher income households tending to have more members. It should be noted, however, that this relationship is not linear; VMT increases sharply at the lower end of the income spectrum, but then slows and levels off. The threshold for this leveling cannot be extrapolated to British Columbia, but for perspective, a 2000 San Francisco study found it to be in the range of $25,000 - 30,000 US per capita.

Age distribution undoubtedly plays a role in the correlation between income and mileage, as both adolescents and retired persons have low annual mileages. However, social class also appears to contribute. A Scottish national survey found that "the average distance travelled per person per year varied greatly with the socio-economic group of the head of the household." For example, people in households headed by a professional or a manager averaged nearly 10,000 miles per year (either as a driver or as a passenger), fifty percent higher than the national average. This difference in mileage was even greater when only miles traveled per person as a driver were considered (Scottish Executive, 2005). The overwhelming pattern, therefore, is that VMT is correlated with income, age and class.

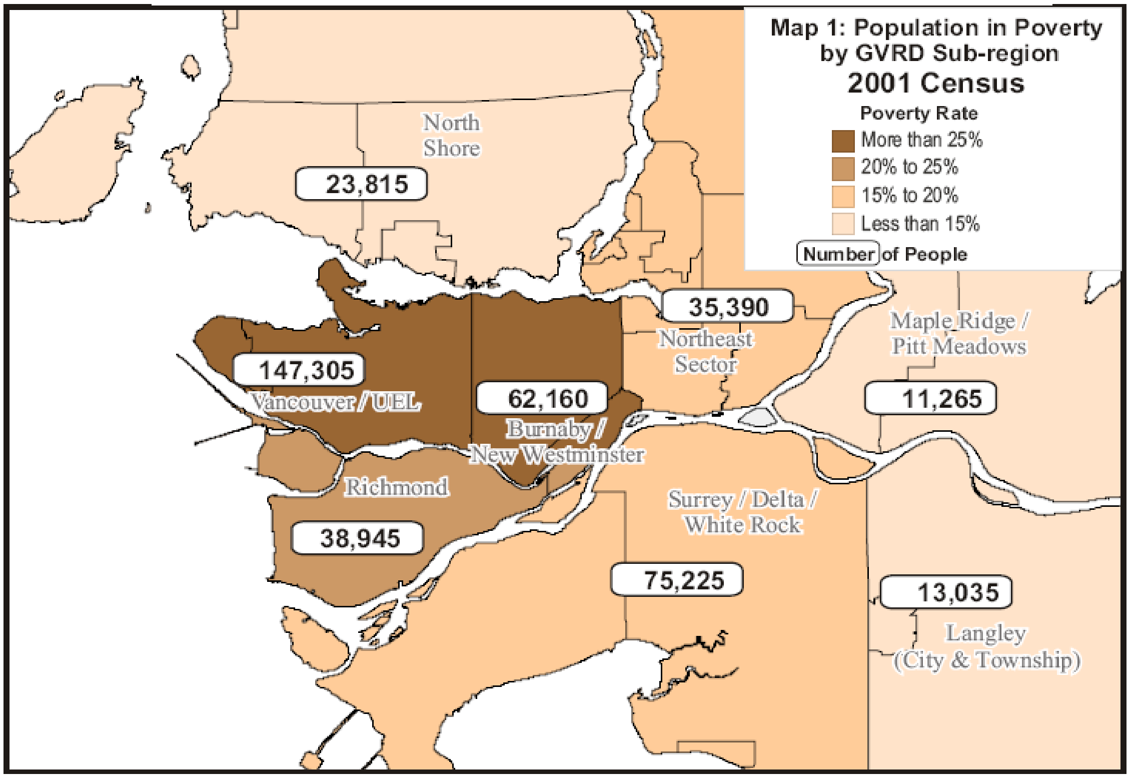
Despite the strong relationship between income and mileage, there is some evidence that this trend does not hold at the highest and lowest ends of the income spectrum. For example, a study of San Francisco households found that although VMT generally increases with income, it declines slightly for households in the top income bracket (Holtzclaw, 2000). This pattern might be expected to hold in British Columbia, where some high-income households are located in central areas, such as downtown Vancouver. Even if this is true, however, it is a small aberration and does not negate the overall progressiveness of a per-km fee.

More concerning is the possibility that low-income drivers may have little control over their mileage and thus little ability to manage their costs under a distance based program. While low-income drivers may drive fewer miles than average, these miles may be necessary to meet basic needs. For example it has been hypothesized that the poor are forced into long, auto-dependent commutes. The classic version of this theory is John Kain's concept of spatial mismatch. In his 1968 paper, *Housing Segregation, Negro Employment, and Metropolitan Decentralization*, Kain argued that poor blacks are concentrated in central-city ghettos and forced into long auto commutes to low-skill jobs, concentrated in the suburbs. However, while this phenomenon may still exist in many cities, particularly in the US, it has little relevance for contemporary British Columbia. Kain's theory assumes the existence of racial segregation that prevents Blacks from living near workplaces or public transit. This segregation is strong and achieved through methods such as "racial covenants, racial zoning; violence or threats of violence; preemptive purchase; various petty harassments; implicit or explicit collusion by realtors, banks, mortgage lenders, and other lending agencies; and, in the not-so-distant past, the Federal Housing Administration (FHA) and other Federal agencies" (Kain, 1968). This segregation is specifically racial, not economic, as Kain asserts that most low-skilled Whites "live near a direct transit line serving current or potential workplaces" (Kain, 1968). Although there is racial spatialization of housing in the Lower Mainland, it does not resemble Kain's mid-twentieth century Chicago in either magnitude or type.

Kain's second assumption is that low-income, Black neighbourhoods adjoin the central city and are poorly served by public transit, which bypasses them for the Central Business District. In Vancouver, low-income and minority households do reside in areas adjacent to Downtown, such as Mount Pleasant, the Downtown Eastside, and Grandview Woodlands. However, these neighbourhoods have good bus service and access to the Skytrain. As a result, while low-income individuals may have long commutes, most are unlikely to require a car to access employment. This is different from Kain's case study in which service sector jobs for which lower income populations are more qualified are often located at the suburban fringe where housing is not affordable, creating a spatial mismatch. This difference in housing and transportation patterns in the Lower Mainland means that distance based insurance should not disadvantage very low income people.

Perhaps more relevant is a contemporary version of spatial mismatch theory which claims that the poor, who have traditionally resided in inner city neighbourhoods, are being displaced to outlying suburbs with poor public transportation (Ross & Dunning, 1997). There is some evidence to support this supposition. For example, one national US study found that "at low levels of household income, income increases are associated with lower VMT" (Kockelman, 2004). One reason for this finding could be that very low income households have been forced into an auto dependent situation, such as living in an outlying neighbourhood. While this may be an increasing trend, it is currently not the dominant pattern in the Lower Mainland. The region's population living in poverty is concentrated in Vancouver and the inner suburbs. Vancouver, Burnaby and New Westminster alone account for more than half of the region's population in poverty (Census Canada, 1996). The truly outlying, auto-dependent suburbs of Maple Ridge, Pitt Meadows and Langley include only 5.1% of the population in poverty (see Figure 1).

Figure 1 Population in poverty by GVRD sub-region, 2001 Census



North Shore: City of North Vancouver, District of North Vancouver, District of West Vancouver, Lions Bay, Bowen Island
Northeast Sector: Coquitlam, Port Coquitlam, Port Moody, Anmore, Belcarra. Source: Canadian Council on Social Development, Community Social Data Strategy. Urban Poverty Project, Vancouver Data, 2005. Data Source: Statistics Canada, Census of Canada, 2001

Source: Metro Vancouver (2007). 2001 Urban Poverty Project Bulletin: Poverty, Greater Vancouver. <http://www.gvrd.bc.ca/growth/pdfs/Poverty_Bulletins_Final_July2007.pdf>.

Discounting a distance based insurance program based on this small population would deny its potential benefits to other low-income persons who are overwhelming concentrated in central areas with good public transit.

It should be noted that distance based insurance's distributional effects would be most significant in urban areas. Urban or suburban areas tend to have concentrations of both the wealthiest and the poorest households. In contrast, middle-income households are most often found in rural areas (Ross & Dunning, 1997). Because insurance rates are related to residential location, rural and urban/suburban areas fall into different categories. Rural areas, having less extreme income differences, will be less affected by cross-subsidies resulting from either an annual or a distance based insurance system.

1.3.3 Complementary policies

Distance based vehicle insurance is a transportation demand management tool and thus would be most effective if implemented as part of a comprehensive TDM program. Many TDM and TSM (transportation supply management) strategies, such as funding alternative transportation options, including transit and cycling, are well known and are appropriate for supporting a broad range of TDM measures. Some other supporting strategies which are particularly applicable to distance based insurance and are discussed below.

1.3.3.1 Road pricing

Distance based insurance is compatible with other forms of road pricing, such as tolls. This is because distance based insurance is well equipped to reduce traffic throughout the network at varying times of the day. It can also reduce vehicle use in low-traffic and rural areas. In addition to relieving some congestion, this offers safety and health benefits. Tolls, on the other hand, are usually designed to reduce congestion on major roads, particularly at busy times of day. Therefore, while tolls' benefits overlap with distance based insurance, the two mechanisms are not redundant.

In addition, toll revenues can meet different public goals than can distance based insurance. Distance based insurance is revenue neutral; some drivers will pay more and some will pay less for insurance, but the total sum collected by ICBC would remain the same. Distance based insurance, therefore, unlike a toll, is not a tax on driving. In contrast, toll revenues can pay for road facilities or for supporting public transit. They can thus address issues of fairness in other ways, such as reducing subsidies for road building. Distance based insurance cannot directly meet these types of public goals. Therefore, road pricing can complement distance based insurance, by increasing fairness in more areas and by providing different incentives to reduce auto use.

1.3.3.2 Parking

It is probable that distance based insurance will increase auto ownership. Under distance based insurance, some people who cannot afford the high sunk cost of annual insurance will choose to insure a car. Other people who already own a vehicle may also choose to insure a second car. This result is not necessarily an undesirable consequence. Opening auto ownership to people without a car will help to correct an unequal distribution of mobility and may open opportunities to disadvantaged people. Enabling ownership of more than one vehicle may also result in a more rational use of those vehicles. For example, people who currently own a large car for recreation or carrying large loads may choose to also insure a smaller car for everyday use. This could reduce emissions by encouraging the everyday use of fuel efficient cars.

The magnitude of this increase in auto ownership is unknown. One transportation economist predicts a 1% increase in vehicle ownership under distance based insurance (Litman, 2007). However, this figure assumes the near saturation of vehicle ownership throughout North America. In a Lower Mainland context, this assumption may not be valid. Auto ownership rates vary throughout the region. For example, 22% of Vancouver households and 5% of Surrey households do not own a vehicle (GVRD, 2000). Therefore, without additional policies, the increase in vehicle ownership in the GVRD might be greater than the predicted 1%.

This increase in vehicle ownership would not be a problem in some parts of the GVRD. For example, some suburban households may have excess garage space to store a vehicle. However, inner-city or other high-density neighbourhoods may not have the capacity for more cars on the street or in underground parking garages. In order to manage an increase in vehicle ownership, it may be necessary to implement or amend some parking policies. Some potential policies have already been developed to meet TDM or other public goals. For example, some Lower Mainland municipalities encourage developers to decouple parking and unit costs. At this time, constructing an underground parking space in Vancouver cost an average of $30,000, with the cost exceeding $40,000 in some circumstances (Flanigan, 2007). The cost of buying an additional parking space at this rate would likely deter most high-rise residents from insuring additional vehicles. Similarly, if on-street parking became too scarce in other neighbourhoods, space could be rationed through permits.It would also be possible to charge a base fee for insuring a vehicle in addition to a per-km charge. In addition to covering administration costs, this would discourage households from purchasing additional vehicles.

Table 2 Existing distance based insurance programs

Insurance Company	Program Name	Location	Date	Pricing System	Billing	Status
Norwich Union (Aviva)	Pay as you Drive	United Kingdom	2003 - present	-Temporal/Spatial Pricing -Individual drivers' rates include standard insurance rating factors (ex. Experience, driving record) -Base fee to cover comprehensive claims -Young driver pricing	Monthly billing	Existing
Progressive	Autograph	Texas	1998-2000	-Discount for below average mileage -Incorporated standard insurance rating factors -Tracked temporal/spatial driving patterns, but not included in pricing	Annual billing	Pilot
Progressive	TripSense	Minnesota, Oregon and Michigan	2004 - present	-Discount for below average mileage -Incorporated standard insurance rating factors -Tracked temporal driving patterns, but not included in pricing	Annual billing	Pilot
Progressive		Iowa	2006-present	-Per-km pricing (odometer readings)	Annual billing	Pilot
Hollard	Pay as You Drive	South Africa		-Base fee -Per-km fee for driving in excess of 417km per month, to a maximum of 3200km	Monthly billing	Existing
Polis Direct			2004 -		Annual rebate for lower mileage drivers	Existing
Aviva (Norwich Union)	Autograph	Ontario	2005 - present	-Temporal/spatial pricing -Driving behaviour pricing (ie. speeding)	Monthly billing	Pilot
Unigard	Pay as You Drive	King County, Washington		-Temporal pricing		Research
AIOI	Pay as You Drive	Japan	2005 - present	-Per-km fee	Monthly billing	Existing

Source: AIOI Insurance Company (2005). AIOI Annual Report 2005. < http://www.ioi-sonpo.co.jp/en/ar_pdf/ar2005e_01.pdf>., Aviva Canada. Introducing Autograph™:The first insurance program in Canada to reward responsible drivers with lower premiums. <https://www.avivacanada.com/autograph/product.php?content=AUTOGRAPH_CONSUMER&language=ENGLISH>., Federal Highway Administration, Office of Policy. (2005). Allen Greenburg. Applying Mental Accounting Concepts in Designing Pay-Per-Mile Auto Insurance Products. <http://www.tinbergen.nl/agenda/tilectures/greenberg.pdf>., Hollard Insurance. Hollard Pay as You Drive: Drive less, pay less. < http://www.payasyoudrive.co.za/articles/vehicle-insurance-quotes.html>., Insurance-Canada.ca. Aviva Canada "Autograph" Program Enables Drivers to Align Driving Habits with Lower Auto Insurance Premiums. < http://www.insurance-canada.ca/consinfoauto/Aviva-Autograph-410.php>., King County Department of Transportation. Pay-as-You-Drive (PAYD) Insurance Pilot Project. < http://www.metrokc.gov/exec/news/2007/pdf/Payasyougofacts.pdf>., Norwich Union. “Pay as you drive”™ insurance. <http://www.norwichunion.com/pay-as-you-drive/index.htm?qreferer=/>., New York Times. Matthew L. Wald. Pay-as-You-Go Plan for Car Insurance. December 22, 2000., <http://query.nytimes.com/gst/fullpage.html?res=9F0DE6D71F39F931A15751C1A9669C8B63>., Seattle Post Intelligencer. Gregory Roberts. Drive less during rush hour, get a lower insurance rate. March 4, 2007. < http://seattlepi.nwsource.com/transportation/309180_kingtrans28.html>., Progressive Insurance. (2006). Basing Auto Insurance on Exact Odometer Readings: Another Pricing Innovation from Progressive Direct <http://newsroom.progressive.com/2006/February/Iowa-mileage.aspx>., Transport Canada. GPS-based insurance pricing <http://www.tc.gc.ca/programs/environment/UTSP/TDM/prj47e.htm>., Washington Post. Albert B. Crenshaw . Basing Car Insurance Risk on the Individual. <http://www.washingtonpost.com/wp-dyn/articles/A64472-2004Aug14.html>.

1.4 The political context

1.4.1 History of marginal vehicle insurance pricing

Distance based insurance is currently offered by private insurance companies in the United Kingdom, Israel, South Africa, The Netherlands, Sweden and Japan (see Table 2). At the present, time of day pricing, with in-vehicle monitoring systems, are dominant. For example, Norwich Union has offered distance based insurance, through an in-vehicle monitor, since 2003 in the United Kingdom. Rates are determined according to standard insurance rating factors (ex. driving experience, driving record) as well as by distance and time of day. The company also charges a base fee to cover comprehensive (non-crash related) claims. Norwich Union, under the name Aviva, is now piloting a similar program in Ontario.

Major pilots of distance based insurance have tested similar programs in different jurisdictions. An example of this is Progressive County Mutual, which has conducted major US pilots of distance based insurance since 1998. Its first two test programs, Autograph and Trip Sense, were both based on combining traditional insurance rating factors with mileage. They also collected data on distance, time of day and location, although these were not used in computing fees. This data collection suggests an interest in temporal and spatial pricing system, similar to that used by Norwich Union.

Last year, Progressive also launched an odometer-based pilot program. This is significant, because a simple version of distance based insurance, incorporating only standard rating factors and distance, has been permanently offered only in Japan. Because Progressive has previously collected data for designing a temporal or spatial fee structure, this may be an indication that they are beginning to see advantages to a simplified system.

1.4.2 History of distance based insurance in British Columbia

Distance based insurance has been endorsed by local governments, including the City of Vancouver and Metro Vancouver, as well as by transportation lobby groups, such as Better Environmentally Sound Transportation. Despite this, there has been limited public discussion about the proposal, especially when compared to other transportation pricing mechanisms, such as tolls and parking taxes.

It is not commonly known that ICBC commissioned two reports on distance based insurance, completed in January 1999, titled *Distance based Vehicle Insurance – Potential for Implementation in British Columbia: General Report* and *Technical Report*. These reports are partially available to the public through the Freedom of Information Act. Subsequent to these reports, ICBC conducted focus groups in preparation for a trial of distance based insurance. The pilot was abandoned after the proposal proved unpopular in the focus groups. Much of the opposition was sparked by the plan to track location and driving behaviour through a GPS system. ICBC was particularly surprised by the widespread rejection of the technology, especially among parents of adolescents whom ICBC expected would welcome a method of monitoring their children’s location and driving behaviour. Partially because of this public unpopularity, ICBC may be reluctant to pursue another trial of distance based insurance unless controversial issues, such as privacy, are addressed. Utilizing GPS technology is clearly not impossible for a distance based insurance program; most existing private distance based insurance programs rely upon similar technology. However, the strong public reaction against the technology may be a barrier to widespread implementation in B.C. This issue should not preempt a discussion of pricing systems which rely upon this technology. However, the issue of privacy should be seriously considered and weighed against the benefits offered by GPS reliant systems.

1.4.3 Current insurance pricing

Current insurance pricing

ICBC's basic annual premiums are calculated based on three main factors:

- Residential location/"territory"
- Rate class
- Driving record

Residential location is a proxy for traffic density, as "if you live in an area with more traffic, you have more chance of being in a crash. Your insurance will cost you more in a big city than it will if you live where there is very little traffic" (ICBC, 2007). Rate class denotes the vehicle's main purpose. ICBC's rate classes are:

- Pleasure
- To and from work (over 15 km)
- To and from work (under 15 km)
- Commute to park and ride.

Driving record takes into account the dates and number of past at-fault accidents. Pending B.C. Utilities Commission approval, this factor will also include driver convictions. For optional insurance, the type of vehicle is also considered. Unlike many private insurance companies, ICBC does not officially use demographic information in rate setting.

Insurance in British Columbia is mainly purchased in two components:

- collision coverage
- comprehensive coverage.

Collision coverage insures against damage to a car from impact with another vehicle, person, object or the surface of the road. Comprehensive coverage insures against theft, vandalism and natural or man-made disasters. It also covers windshield damage resulting from falling or flying objects, including rocks or gravel.

Collision coverage is priced by these rating factors:

- Residential location
- Type of car
- Driving record

Comprehensive coverage is priced by these rating factors:

- Location of residence
- Type of car

Basic Autoplan insurance, which is mandatory, included a minimum coverage for collisions. Additional collision coverage and comprehensive coverage are optional, but widely purchased.

1.4.4 Opportunities for implementation

In the long-term, BC's economic and institutional context provides opportunities for mileage-reduction programs. For example, as BC does not manufacture vehicles or extract petroleum in significant quantities, there is little provincial economic value in promoting auto use. Also, ICBC's position as a crown corporation, mandated to serve the public good rather than create profit, as well as its near-monopoly, makes it particularly suited to implementing a marginal-cost insurance program. On one hand, ICBC lacks the flexibility and freedom of a private company. This disadvantage, however, is perhaps outweighed by its potential to make a widespread change, rather than targeting only a limited sub-market, such as low risk, low mileage drivers, for distance based insurance. This wide reach is important for distance based insurance to have an impact on pollution and congestion. Furthermore, as a crown corporation, ICBC reports to the provincial government. It therefore can be mandated to adopt a new pricing strategy if the government determines that it would be in the best interest of British Columbia.

1.4.5 Real and perceived barriers to implementation

Several barriers to implementing a distance based insurance program were identified through discussions with transportation and insurance professionals. Some of these barriers are more speculative than others. However, any proposal for a distance based program must address them to some degree in order to be acceptable to stakeholders.

1.4.5.1 Political/legal approval

Because ICBC is a crown corporation, any insurance pricing changes must be supported by the provincial government. In addition, ICBC rate changes are subject to the BC Utilities Commission's approval. The Commission has a mandate to preserve actuarial accuracy for mandatory vehicle insurance. In addition, it is influenced by many interest groups, including ICBC's competitors, seniors' advocacy groups and individual citizens. Per-km vehicle insurance, depending on its design, may affect the insurance rates of certain groups, such as seniors. Therefore, these constituencies' influence on the BC Utilities Commission should be considered in designing a politically feasible proposal.

1.4.5.2 Actuarial accuracy

In order to preserve actuarial accuracy and reduce ICBC's risk, a distance based system must still incorporate current insurance rating factors. With the possible exception of rate classes, which are a proxy for distance, these rating factors can be incorporated into distance based fees.

Simply, drivers who are considered higher risk because of their driving record or because of where they drive can be charged a higher per-km rate.

One additional consideration in maintaining actuarial accuracy is the issue of 'low mileage bias.' This term refers to a hypothesis that drivers with low annual mileages have a disproportionately high per-km risk. This could be because they tend either to drive a disproportionate number of their mileage under higher risk conditions or tend to be worse drivers, for example because of their age. A distance based insurance program would need to address this issue in order to maintain actuarial accuracy and fairness.

1.4.5.3 Public opinion

A large number of auto drivers would save money on their insurance under a distance based insurance program. Drivers whose mileage is below average for their rate class will, of course, save money. Additionally, average mileage drivers who reduce their driving can also reduce their bill. This means that over half of drivers could potentially save money on their insurance (Litman, 2007).

Despite this majority of 'winners,' there may still be significant opposition to a change in the insurance system. There may be a resistance based on values, which may be partially geographic. For example, it may be considered that an auto-dependent lifestyle is a right, which should be subsidized by the government or by other drivers. This barrier may be compounded by poor understanding of both annual and distance based insurance. Currently, urban, suburban and rural residents pay different annual rates, based on their residential location's traffic density and the average annual mileage of an area's residents. Under a distance based program, urban drivers would likely pay high a per-km rate, because they drive in high-density traffic. However, their lower average mileages would help to counter-balance this, resulting in premiums which are similar to what they pay now. Despite this reality, the actuarial system is poorly understood in British Columbia. As a result, there is a public misconception that distance based insurance will simply reduce urban drivers' rates while increasing suburban rates. It is true that urban drivers with more transportation options may have more opportunities to reduce their mileage. However, under a well-designed system, this outcome would not affect suburban drivers' premiums.

Finally, ICBC's past experience with focus groups suggests that privacy may be a challenge for some models of distance based insurance. This includes those which employ GPS to apply time-of-day or road facilities pricing. This barrier likely does not apply to other systems, such as those based on odometer readings. While ICBC has some preference for temporal pricing, which requires the use of GPS, a simple mileage-based pricing system is also feasible.

It should also be remembered that simple inertia can prevent even the most appealing policy changes. The current system may reflect this effect more than any substantial technical or political barrier to distance based insurance. It is possible to implement interim or pilot programs which address inertia or resistance. For example, ICBC could offer an optional program in which motorists record and report their annual mileage. Those who drive less than the average mileage for their rate class would receive a discount. This short-term program could be provincially funded. A pilot such as this could reduce uncertainty about the implications of a new pricing system and build a constituency of drivers supportive of distance based insurance.

1.4.6. Options for distance based insurance

While distance based insurance has been widely proposed by transportation planners, there is little consensus on the design of a system. Although there has been little discussion of the options, the current proposals fall into five main categories:

- **Flat-rate pricing** – All drivers are charged the same per-km rate for every kilometer.
- **Differential pricing –** A base fee or higher fee on initial kilometers is charged in order to account for low mileage bias
- **Temporal Pricing** – Different per-km fees are charged depending on the time of day and/or day of the week. All drivers are charged the same rates.
- **Spatial/Road Type Pricing** – Kilometers driven on roads with different accident risks are charged at different rates. All drivers are charged the same rates.
- **Demographic Pricing** – Drivers are charged different per-km rates, depending on the risk of their demographic characteristics. Driver age is the most significant predictor of crash risk, and the only characteristic like to be considered in rate-setting.

Temporal, road-type and demographic pricing can be combined into a pricing system in several different ways. For example, a single index of temporal risk could be applied at different rates, according to age. Alternatively, as different age groups have different temporal risk patterns, a number of age-based temporal risk indexes could be created.

Although these different pricing systems may seem to be technical details, each would have significant social and economic implications. Because they treat risk in very different ways, each would have different effects on the insurance system and on its cross-subsidies between drivers. These changes could impact the insurance system's fairness and equity as well as the distribution of mobility among British Columbia's residents. As a result, before implementing any of these distance based systems, it is important to understand the distribution of driving risk across time, across space and across the population. It is then necessary to examine both how the current insurance system and various proposed distance based systems account for risk. This will allow the proposed systems to be evaluated against their impacts on public policy goals.

1.4.7 Optional programs

It is possible to mandate distance based pricing in British Columbia or to offer it as a consumer option. Although optional distance based pricing offers fewer immediate benefits, it would likely be more publicly acceptable. However, if low risk, low mileage drivers, who would benefit most from distance based pricing, choose this option, their subsidy of high risk and high-mileage drivers would be reduced. As a result, premiums for drivers in the conventional program would gradually rise to reflect their true annual risk. Because of this, there would always be an incentive for drivers with mileages below the average of the annual program to switch to the distance based program. This would likely lead to a wide adoption of distance based insurance. Because of this, the difference between a mandatory and an optional program is more theoretical than practical. This report's conclusions can be applied either to a mandatory program or to the portion of drivers who choose a distance based program.

It has also been suggested that distance based insurance be offered as an option only to low risk drivers. This might include either drivers with good driving records or drivers in certain demographic or geographic categories. This type of selection is unnecessary for a successful program. In fact distance based insurance will realize the greatest benefits by including high risk drivers, as it incentivizes participants to reduce their driving. What is necessary is to ensure that high risk drivers' per-km premiums reflect their elevated risk. As all drivers' per-km fees should be based on their current annual fees, high risk drivers are not an exception to the pricing system. Despite this general principle, particular issues related to high risk drivers will be addressed in Section 3 of this report.

1.4.7.1 Collision and comprehensive programs

Both collision and comprehensive insurance can be offered under distance based pricing as both collisions and comprehensive claims rise with increase distance driven. A study of ICBC data has shown that

> [comprehensive] claims do increase with annual vehicle kilometers […] (excepting very high-mileage classes, which are probably inaccurate). Driving increases a vehicle's exposure to comprehensive-coverage risks, including paint and glass chips that occur while driving, and other damages if away-from-home parking this is less secure than at-home parking. This indicates that distance based pricing should apply to all types of insurance coverage" (Litman 2005).

It is possible that the relationship between mileage and comprehensive claims is less linear than of that between mileage and collisions. To account for this it is possible, as some private insurers have done, to charge a base fee that represents a portion of comprehensive claims. As little information on comprehensive claims is publicly available, this issue should be subject to further discussion, informed by ICBC's own data.

2 ACTUARIAL ISSUES AND CRASH PATTERNS

One of the major barriers to implementing distance based insurance in British Columbia is the BC Utilities Commission's requirement of maintaining actuarial accuracy. Because the BC Utilities Commission is subject to Provincial legislation, this requirement may be possible to change. Nevertheless, its existence suggests an existing preference for accuracy. Even if actuarial accuracy is not required, any changes in insurance pricing will shift cross-subsidies between groups of drivers, thereby impacting fairness and equity. For this reason, understanding collision patterns and their relationship to current and proposed pricing systems is an important subject of public discussion in British Columbia.

2.1 Current system

ICBC, like most North American insurance companies, currently charges an annual, fixed rate for vehicle insurance. Drivers are divided into actuarial groups based on rating factors. A driver's annual insurance fee is related to both the average annual mileage and the average per-km accident risk of drivers in their actuarial group.

ICBC's main rating factors are proxy measures of some types of risk. For example, residential location is a proxy for road type. Although there is no official age rating, rates based on years of driving experience also function as a proxy for age. These rating factors are very crude in comparison to the known demographic, spatial and temporal aspects of risk. Distance based insurance, if it was implemented through GPS technology, has the potential to more precisely measure a motorists' risk, for example by tracking their mileage by time of day or by road type. It is also possible to charge different fees based upon demographic characteristics, such as age, gender or marital status. Although this is not legally possible at the present time in B.C., it is widely practiced by private insurance companies elsewhere in North America. Even though implementing these rating factors would be difficult, it is not impossible. Demographic pricing's illegality suggests that there is some public or political preference against this type of discrimination. Despite this, if the political climate changes, the provincial government has the authority to both repeal the legal barriers to demographic pricing and to instruct ICBC to utilize them in pricing. However, although demographic pricing is technically possible to implement, it may not be desirable. Demographic risk factors have complex patterns, including complicated interactions with each other. This means that incorporating more precise measures of risk into insurance fees would be technically difficult and thus potentially costly. It may also be politically challenging. Therefore, it is worth exploring whether more precise pricing would create benefits that would outweigh the logistical and political obstacles to its implementation.

In examining risk, it is important to remember that the most costly accident category, overall, is injury involvements, followed by property damage. Fatal accidents, while individually expensive, are a relatively small proportion of an insurance company's costs (KPMG, 1996). Therefore, an emphasis will be given here to per-km risks of injury involvements.

2.2 Collision patterns

2.1.1 Notes on data

Much American research on per-mile crash patterns utilizes one of two databases, the Fatal Accident Reporting System (FARS) and the General Estimates System (GES) to provide crash data. FARS includes all accidents which result in a death up to thirty days after the incident. GES is a less comprehensive database, composed of police accident reports from sixty areas that "that reflect the geography, roadway mileage, population, and traffic density of the U.S." (National Highway Traffic Safety Administration, 2007).

These sources are more reliable for some types of crashes than for others. Fatality rates, from both FARS and GES are more reliable than injury and property damage crash rates. FARS more accurately records fatality rates because it includes all fatal crashes, rather than a sample. In addition, because GES includes only police-reported crashes, many minor injury and property damage crashes are uncounted. This bias towards counting fatality and serious injury crashes likely distorts some crash patterns. For example, as seniors are more likely to be seriously injured in a crash, their overall crash rates may be exaggerated in comparison to the younger population. Although the uncounted crashes may not be reported to police, many will still trigger an insurance claim. They would thus have implications for a distance based insurance program. Therefore, in examining crash patterns, it is important to keep in mind the underreporting of minor crashes.

FARS and GES crash data is usually combined with mileage estimates taken from the Nationwide Personal Travel Survey (NPTS)[1]. The NPTS is a daily travel survey of a sample of American households, completed approximately every seven years. It has traditionally been conducted through questions about the previous day's travel, but in 1995 there was a switch to travel diaries. Until 1995, the survey required a minimum of only one adult respondent per household. After 1995, at least half of the adults in the household were required to participate for the household's data to be counted. However, it is possible for one respondent to respond in proxy for other members. These proxy reports tend to underreport trips (Sharp & Murakami, 2004). If some types of household members are more likely to respond to the survey, this would bias the results. The direction of this possible bias is unknown. Another limitation of the NPTS is that it a phone survey. Because of this, it likely undercounts minorities and low-income groups as well as large households, whose burden of reporting is high (Sharp & Murakami , 2004). It also undercounts groups that have high cell phone only use. However, the omission of this last group is irrelevant for this report which mainly utilizes research that predates the wide usage of call phones. A final issue with the NPTS is that its small sample size makes it appropriate only for use at the national level of analysis. This principle is adhered to by the research utilized in this report. A few studies cited on this report are from other countries, such as Australia, which draw upon similar national travel surveys.

In addition to research on national patterns, some studies of smaller areas employ their own surveys of exposure and driving behaviour. Their methods are more diverse, but their goals are usually either to derive data for an area that is too small to apply NPTS data or to gather more detailed information about travel patterns. A few studies also employ demographic surveys that are used in conjunction with GPS tracking of travel patterns and driving behaviour. These studies, mainly conducted at the state and regional levels, have found patterns which are very

[1] In 2001, the NPTS was combined with the American Transportation Survey to form the National Household Travel Survey (NHTS).

consistent with national-level research. Although there might be divergences in some areas, the broad demographic and driving patterns examined here seem to be insensitive to regional differences and relatively unaffected by measurement techniques.

In addition to these general limitations, there are some particular data issues related to young drivers and seniors. Although some research on young drivers is part of more general studies of crash risk, much of it is related to justifying or evaluating graduated licensing programs. One of the complications of both types of research, but especially of the latter, is regional differences in the legal driving age and in the existence of graduated licensing programs. There is large variation in crash risk and characteristics for different cohorts of young drivers. Therefore, the age threshold and driving restrictions in place in the study region will affect the reported magnitude and type of young drivers' crashes.

A similar issue potentially exists for older drivers. Australia, New Zealand and some North American jurisdictions have mandatory testing for elderly drivers. Therefore, it might be expected that their older drivers' crash rates would be unapplicable to British Columbia. However, there is evidence that older drivers testing programs have little effect on their crash rates (Rosenbloom, 2003). This is likely because reliable tests for identifying at-risk drivers have not yet been developed (Lyman et al., 2002) and because, in practice, testers are reluctant to restrict a seniors' mobility by revoking their license (Rosenbloom, 2003). This conclusion is supported by Australian and New Zealand accident research, which show almost identical age-related crash patterns to those in North America. This is also true for European countries, such as Finland which have seniors' testing (Hakamies-Blomqvist, Hohansson & Lundberg, 1996). Although the difference in crash rates might make this research unsuitable for precisely calculating actuarial rates, it seems appropriate for outlining general age-related trends. Therefore, in the following sections, different jurisdictions' licensure policies will not be highlighted.

2.1.2 Overall patterns

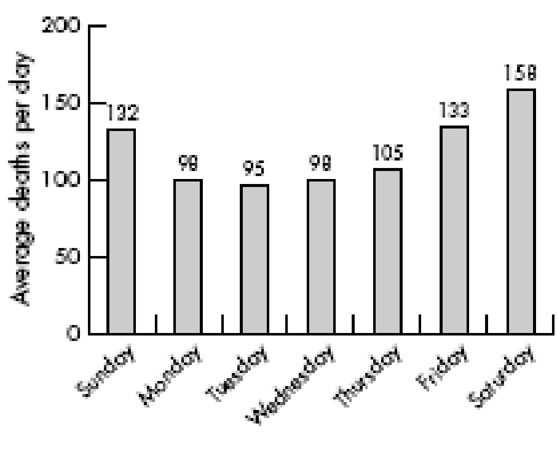
Vehicle crashes occur in complex patterns and are correlated with a large number of variables. However, some variables are more commonly used for insurance pricing, both because of their predictive power and because of their social acceptability. Many of these variables are demographic, such as age, gender and income. Although most of these variables are not currently used, or even legal, in British Columbia, they influence the distributional effects of the current, basically flat-rate system. By ignoring these possible rating factors, the annual system creates subsidies between drivers. Drivers with high risk characteristics or driving patterns are subsidized by lower-risk drivers. The design of a distance based system allows the direction or magnitude of these subsidies to be modified or to be held constant. Therefore, an understanding of such risk patterns is important in designing a publicly acceptable distance based system. Additionally, some proponents of distance based insurance have suggested incorporating additional rating factors into a distance based system, primarily through temporal and spatial pricing. This is a reason to examine these aspects of crash risk. The following analysis will be mainly confined to the most influential and widely used risk factors:

- time of day and week
- road type
- age and gender.

2.1.2.1 Time of day

Time of day and road type pricing has been advocated by some proponents of distance based insurance. Therefore, the temporal and spatial patterns of vehicle crashes are worth examining. Unfortunately, there is little comprehensive research on temporal per-km risk. However, research on the absolute number of crashes provides some insight into the distribution of risk. Some temporal crash patterns are well documented. Fatal crashes are lowest from Monday to Thursday and highest on Friday and Saturday. Sunday has a higher number of fatal crashes than the weekdays, but less than Friday and Saturday (Farmer & Williams, 2005) (See Figure 2).

Figure 2 Crash deaths by day of week, 1986 - 2002

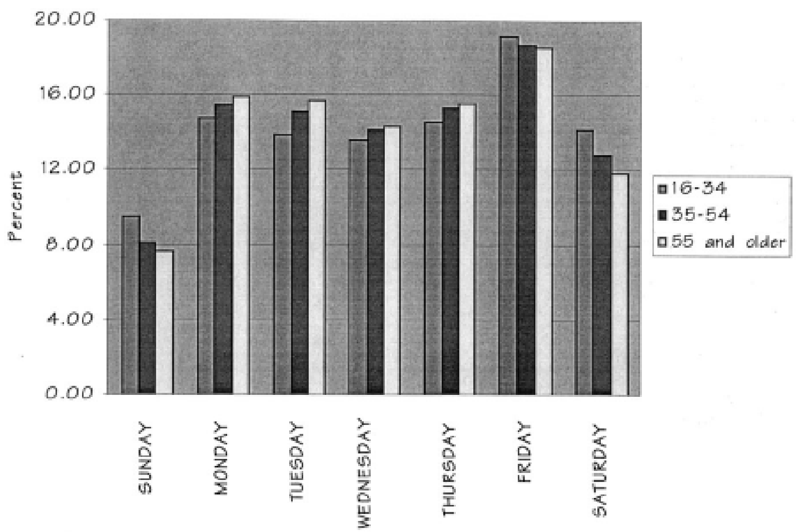


Source: Farmer, C.M. & Williams, A.F. (2005). Temporal factors in motor vehicle crash deaths. Injury Prevention., 11, 18-23.

It seems likely that this high Sunday rate is an artifact of measurement, and actually reflects crashes that occur past midnight on a Saturday night. More precisely, fatalities are most common in the hours around midnight on Friday and Saturday nights, while other days "have lesser peaks in the afternoon and around midnight" (Schwing and Kamerud 1988). The relationship of these absolute crashes to mileage has not been fully explored. However, it is clear that the high risk of evening and weekend travel is not a result of the concentration of mileage at these times. For example, one study found fatality rates to be much higher on the weekend although weekend mileage is only slightly higher than weekday travel (Schwing and Kamerud 1988). It found fatality rates to be very temporally concentrated, as the most dangerous 1% of travel [by time of day] results in 17% of all fatalities, the most dangerous 5% of travel in 34% of all fatalities, and the most dangerous 10% of travel in fully 42% of all fatalities (Schwing and Kamerud 1988).

This strong temporal concentration of fatal crashes, both absolutely and per-km, should not be extrapolated to all crashes. Overall crashes, by absolute number, do follow a similar, but not identical, pattern to fatal crashes. The highest number of crashes occurs on Friday. But unlike for fatal crashes, Sunday has the lowest number of crashes, followed by Saturday. The weekdays, from Monday to Thursday, all have similar rates and fall in the middle (McGwin & Brown, 1999) (see Figure 3).

Figure 3 Distribution of total crashes by day of week and by age



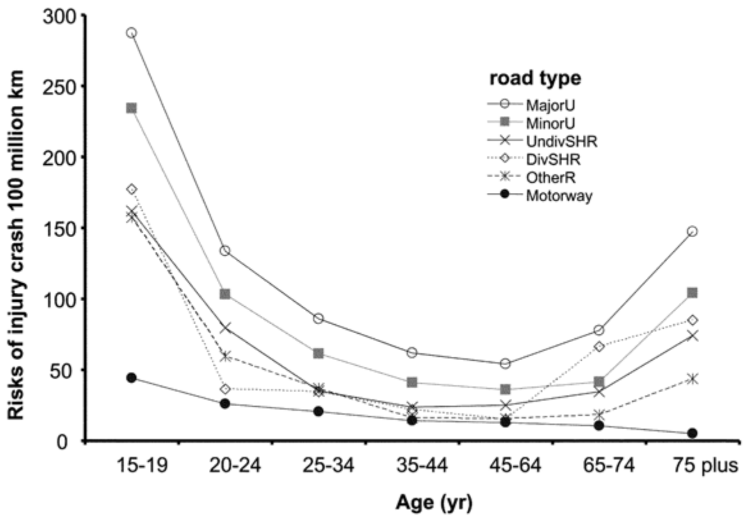
Source: McGwin, G. Jr., & Brown, D.B. (1999). Characteristics of traffic crashes among young, middle-aged, and older drivers. Accident Analysis and Prevention. 31(3), 181-98.

Importantly, the variation in total crashes across the week is much less than for fatal crashes. For example, while Friday does have the highest overall number of crashes, the number is less than twenty-five percent higher than that of a typical weekday. As injury and property damage crashes are far more costly overall than fatality crashes, this more even distribution of crashes is more important than the highly concentrated fatal crashes.

2.1.2.2. Road type

There is more conclusive evidence based pertaining to risk across road facility type. Overall, major urban roads are most dangerous, followed by minor urban roads, several types of rural roads and finally by freeways (Keall & Frith, 2004) (See Figure 4). These relationships are a function of travel speed and volume.

Figure 4 Risk of injury crash involvement by road type and age



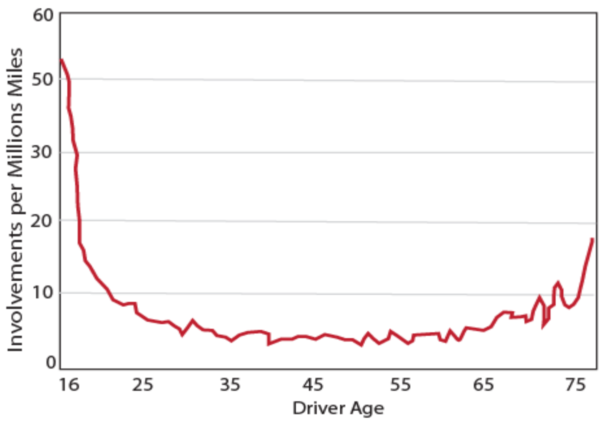
Source: Keall, Michael D., & Frith, William J. (2004). Older driver crash rates in relation to type and quantity of travel. *Traffic Injury Prevention. 5(1)*, 26-36.

With the exception of freeways, these patterns are consistent across all age groups. However, this clarity of this pattern is tempered by other factors. For example, although rural roads have lower overall crash rates, their crashes tend to be more serious (Keall & Frith 2004) and to include most fatal crashes (US Department of Transportation, 2001). Another complication is that the risk of different road types varies significantly by time of day. For example, most roads have higher per-km crash rates at night than during the day. However, higher-volume roads, because of illumination, are no riskier at night than during the day, except on weekends (Keall, Frith, William, & Patterson, 2005). As these roads carry a large portion of vehicle mileage, this exception is not trivial. This difference in road-type risk across the week suggests that if temporal and road type were applied together to estimate risk, the risk patterns might be more complex than if either category was examined alone.

2.1.3 Demographic patterns

The most significant demographic risk category is that of age. Research consistently shows that per-km crash patterns appear as a U-shaped curve, with drivers over 60 and below 30 having elevated crash risks (Cooper 1990; Hakamies-Blomqvist 1994; Massie & Williams, 1995; McGwin & Brown, 1999; Retchin & Anapolle, 1993; Ryan, et al., 1998, Schlag, 1993; Stutts & Martell, 1992). The exact age range for elevated risk does depend on the researchers' subjective judgment about where the increase in slope becomes significant. As Figure 5 shows, in terms of youth crashes, the crash rate falls significantly between ages 20 and 25. It declines more slowly until age 30, when it is almost identical to that of middle-aged drivers. At the other end of the spectrum, risk increases slightly between age 60 and 65, but does not become highly elevated until about age 70. This pattern is similar whether examining total crashes, fatal crashes or injury-producing crashes (see Figures 5-7). Looking closer, the curve for all crashes and for injury crashes is steeper for the young than for the old (see Figures 5 and 6).

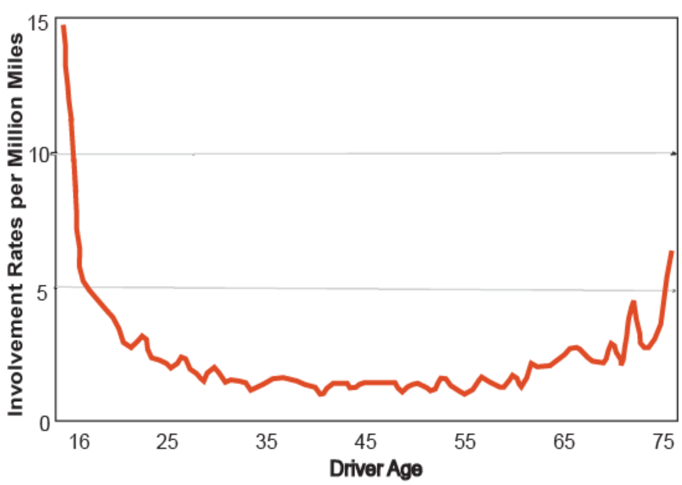
Figure 5 All crashes per 100 million miles, 1990 GES and 1990 NPTS



Source: Massie, D.L., Campbell, K.L. (1993). Analysis of accident rates by age, gender, and time of day based on the 1990 nationwide personal transportation survey. The University of Michigan Transportation Research Institute. Ann Arbor, Michigan.

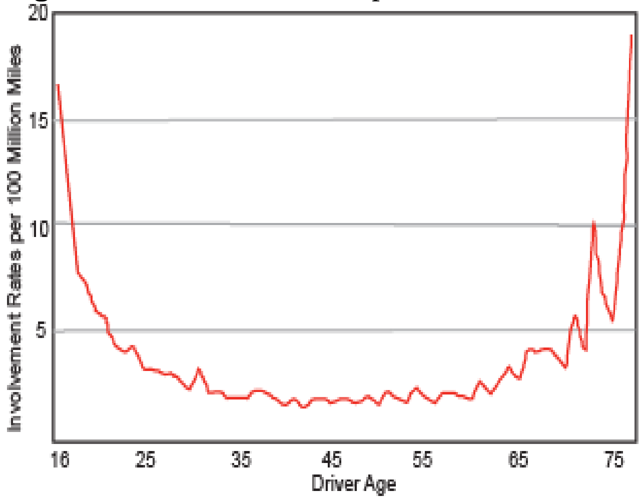
In contrast, the curve for fatal crashes is sharper for the old than for the young (see Figure 7). This means the oldest drivers have a high risk of being in a fatality-involving crash , while the youngest drivers are most likely to be in any crash as in an injury-involving crash. This phenomenon's causes and implications are complex and require further examination.

Figure 6 Injury crashes per 100 million miles, 1990 GES and NPT



Source: Massie, D.L., Campbell, K.L., & Williams, A.F. (1995). Traffic accident involvement by age and gender. Accident Analysis and Prevention. 27(1), 73-87.

Figure 7 Fatal crashes per million miles, 1990 FARS and 1990 NPTS



Source**:** Massie, D.L., Campbell, K.L., & Williams, A.F. (1995). Traffic accident involvement by age and gender. Accident Analysis and Prevention. 27(1), 73-87.

2.1.3.1 Young drivers

2.1.3.1.1 Overview of crash patterns

'Older' and 'young' drivers are very broad categories. Similarly, the category 'crash' can obscure the causes, the level of severity and other characteristics of a group's crashes. Therefore, each group's crash risk should be examined in more detail to limit the distorting effects of aggregation. First, the main causes of a group's crashes affect these crashes' characteristics. For young drivers, a high crash rate results from "a combination of inexperience in assessing traffic situations and a willingness to risks for a number of reasons" (Catchpole, Cairney & MacDonald, 1994). These risks include unsafe driving behaviour such as speeding, (Elander, West & French, 1993), tailgating, unsafe acceleration and rapid lane changes (Jonah, 1986; Preusser, Ferguson, & Williams, 1988). They also include drinking and driving.

As a result of this behaviour, young drivers, as a cohort, have unique crash patterns. Risky driving behaviour and alcohol use are associated with night-driving (Farrow 1987). Alcohol-related crashes more often take place on weekend nights, on unlit and minor roads and are more likely to be single-vehicle crashes. They are also more likely to be crash types, such as rollovers, which result in more serious injuries and fatalities (Kim et al., 1995). Young drivers' crash patterns do indeed reflect these risk factors. For example, young drivers are over-involved in single-vehicle crashes (Ryan et al., 1998; Williams et al, 1995) and in fatal crashes, (Massie & Williams, 1995). These different crash types and temporal and spatial patterns distinguish youth from the rest of the driving population.

2.1.3.2 Time of day and road type

These patterns of risk taking also affect the temporal patterns of young drivers' crashes. Young drivers' relative nighttime to daytime risk, for all types of crashes is highly elevated compared to that of middle-aged and older drivers (Massie & Williams, 1995; Mortimer & Fell, 1989). This temporal pattern is particularly true for fatal crashes (see Figure 8). For example, American sixteen year old drivers accumulate only fourteen percent of their miles between 9 p.m. and 5:59 a.m., but thirty-nine percent of their fatal crashes occur during these hours (Williams & Preusser, 1997). The result of this is that the nighttime crash rate of drivers aged 20-24 is 6.1 times their daytime crash rate. In comparison, middle-aged drivers' nighttime crash rate is only 1.1 times their daytime rate (Massie & Williams, 1995). These differences result from the fact that young drivers' crash characteristics, including their causes and temporal patterns, reflect not only their inexperience, but also a number of risk-taking behaviours.

Figure 8 Fatal crash involvement per 100 million miles, day vs night, by driver age, 1990 GES and 1990 NPTS

Image removed due to copyright

Source: Williams, Allan F., & Preusser, David F. (1997). Night driving restrictions for youthful drivers: A literature and commentary. Journal of Public Health Policy. 18(3), 334-45.

2.1.3.2.1 Risk-taking behaviour

Despite these particular accident patterns, it would be mistaken to view young drivers as a homogenous group of reckless and inexperienced motorists. Age in itself defines only a very broad set of characteristics about people. Therefore any sub-stratum of age still contains a great deal of heterogeneity as a function of other demographic characteristics. The overall pattern of risk-taking behaviour does suggest that there is a developmental aspect to risk driving. However, there is also strong evidence that indicates that this behaviour is unevenly distributed across the youthful population.

Although 'young drivers' is an age category used widely by both professionals and lay people, it is very imprecise. Although all types of per-km crash risk are elevated until age twenty-five or thirty, much of the risk is concentrated among the very youngest drivers. For example, for all police-reported crashes, sixteen year olds have a rate 7.1 higher than the overall rate. In only a year, this drops to 5.0 times the overall rate. It again falls sharply after this (Massie & Campbell 1995). The pattern is similar for fatality rates and even more pronounced for injury crashes, the most overall costly type of crash. While sixteen year old drivers have an injury rate 7.2 times the average, by age nineteen, their rate is only 2.3 time higher (Massie & Campbell, 1995). While this is still an elevated rate, it is closer to the rate for middle-aged drivers than to that of the youngest drivers.   Moreover, 'young drivers' in their mid to late twenties have injury rates almost identical to middle-aged drivers (see Table 3).

Table 3 Driver crash involvements per million miles traveled, by age

Age	Total Crash Involvements	Fatal Crash Involvements
16	35	13
17	20	8
18	14	6
19	13	6
16-19	17	7
20-24	9	4
25-29	6	3
30-34	4	2
35-39	5	2
40-44	4	1
49-49	4	1
50-54	4	2
55-59	4	2
60-64	4	2
65-69	4	2
70-74	5	3
75-59	7	5
80-84	12	11
85+	14	16

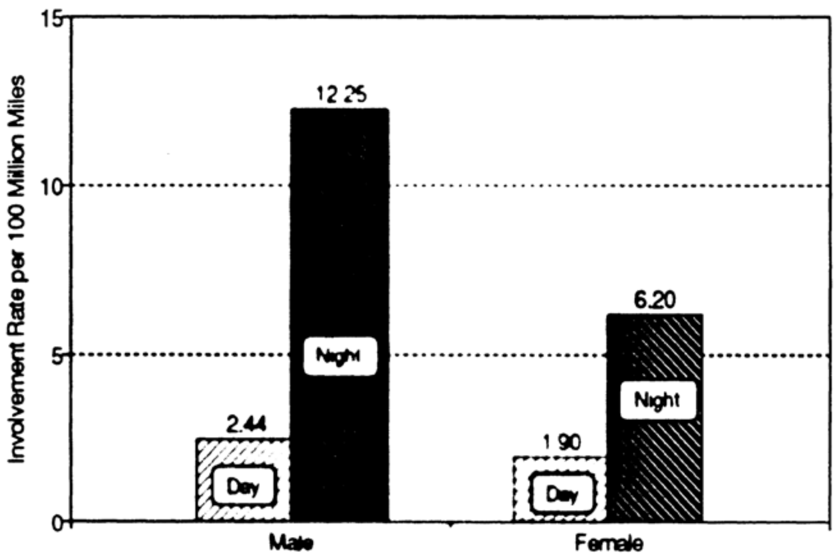
Source: Williams, Allan F. (2003). Teenage drivers: patterns of risk. *Journal of Safety Research* (24(1), 5-15.

This means that the category 'young drivers,' while distinct from a fairly homogeneous group of middle-aged drivers, should be understood as a category that is highly internally stratified.

In addition to age differences, risky driving and its resulting crash patterns, appears to be highly gendered. While young men and women have comparable daytime crash rates, men's nighttime rates are much higher than women's rates for some groups of young drivers. For drivers aged 20-24, men's nighttime crash rate is 4.2 times higher than that of women and their nighttime injury crash rate is 2.7 times that of women (Massie & Williams, 1995) (see Figure 9).

As risky driving is associated with night driving, the most likely explanation for this pattern is that men are engaging in more risky behaviour. However, it seems that a subset of men who are contributing to these high crash rates. It has been suggested that young drivers' high crash rates result from widespread inexperience and risky driving which is compounded by alcohol in a smaller number of cases (Mayhew 1986). Behavioural research, however, suggests that individual youth who frequently drink and drive are also likely to engage in other risky driving behaviour (Jonah 1990; Horwood & Fergusson, 2000). This implies that all types of risky behaviour are likely concentrated within a subset of young drivers. Therefore, the possible perception of youth, or even of young men, as risk-takers is inaccurate; although perhaps most risk-takers are youth, youth are not necessarily risk-takers.

Figure 9 Fatality rates, day vs. night by age, 1990 FARS and 1990 NPTS



Source: Massie, D.L., Campbell, K.L., & Williams, A.F. (1995). Traffic accident involvement by age and gender. Accident Analysis and Prevention. 27(1), 73-87.

In addition to a misperception of the prevalence of risky driving among youth, there may also be confusion about what constitutes risky behaviour. Despite the stereotype of drunk-driving teenagers, teenagers and young adults are actually less likely than older age groups to drive after drinking (Mayhew 1986). When they do drink, however, they have "have a greater risk of crash involvement than older drinking drivers at all blood alcohol concentrations" (Mayhew 1986). There are several possible explanations for this phenomenon. First, young drivers may be more likely to crash, regardless of their alcohol consumption, either because of inexperience or because of other risky driving behaviours. It may also be that driving under the influence is itself a learned skill. If the cause is inexperience in either driving or driving under the influence, youth may still be learning the skills that older drivers routinely employ. There is also some evidence that certain youth are combining other risky driving behaviours with alcohol (Mayhew 1986), although it is unclear whether this is also true of older drivers. Current research does not make it possible to disentangle all of these contributing factors to young drivers' crashes. What is clear, however, is that while young drivers' alcohol consumption may be compounded by their other behaviours and characteristics, they are far from alone in taking the risk of drinking and driving.

2.1.3.2.2 Risk imposed on other road users

Young drivers' crashes impose significant risks on other road users. Some of this risk results simply from their higher crash rates. However, there also seems to be some disproportionate risk that is not encompassed by these rates alone. Crashes are counted as injury or fatality crashes if they include a minimum of one injury or fatality. Young drivers' crashes, however, more often result in injuries or fatalities to other road users, which may be above and beyond this first injury. For example, crashes among drivers under age 20 are associated with more deaths to others (Dellinger, Kresnow, White & Sehgal, 2004; Braver & Trempel, 2004). Compared to older drivers, drivers under thirty also impose high risks of injuries on other road users, including their passengers, occupants of other vehicles and non-occupants. This elevated risk for both injuries and fatalities is significant. For example, the injury or fatality risk to passengers in young drivers' cars is more than five times higher than that for the passengers of 30-59 year old drivers (Braver & Trempel, 2004). This higher risk per crash, when combined with young drivers' high number of crashes, means that young drivers, impose higher risk to other road users, both on an annual (Braver & Trempel, 2004) and on a per-km basis (Dellinger et al., 2004).

2.1.3.3 Older drivers

2.1.3.3.1 Overview of crash patterns

At first glance, older drives have similar crash patterns to young drivers; when graphed, young drivers and older drivers' per-km crash rates appear as the ends of an upward sloping U-curve (see Figure 10).

Figure 10 Per-mile injury, fatal and overall crash rates by age

Image removed due to copyright

Source: Massie, D.L., Campbell, K.L. (1993). Analysis of accident rates by age, gender, and time of day based on the 1990 nationwide personal transportation survey. The University of Michigan Transportation Research Institute. Ann Arbor, Michigan.

This is true for rates of total police-reported crashes, injury crashes and fatality crashes. However, this superficial similarity conceals divergent causes and characteristics of these group's crashes.

The U-curve itself hides a complexity in older drivers' crash patterns. Toward the older edge of the age spectrum, rates for all types of crashes begin to increase at age 55 (McGwin & Brown, 1999). Injury and fatality rates remain only slightly elevated over middle-aged drivers until around age 65 (Massie & Williams, 1995) or 70 (Lyman et al., 2002), when they increase more steeply. Between age 55 and 74, injury crash and fatality crash rates increase at similar rates. These rates are both comparable to that of younger drivers, being "about the same as that of young adults, but lower than that of adolescents" (Massie & Williams, 1995). At age 74, however, the fatality crash rate begins to outstrip the injury crash rate. For example, "while adolescents have 3.0 times the risk of a fatal crash compared to all drivers, drivers over 74 have 3.8 times the overall risk" (Massie & Williams, 1995). The reasons for these complex patterns, particularly the diverging injury and fatality rates, are very different from the factors underlying young drivers' crash patterns. The causes of older drivers' are related to this groups' particular behavioural and physiological characteristics. These characteristics also affect the temporal and spatial patterns of older drivers' crashes.

2.1.3.3.2 Time of day

Older drivers have very different temporal crash patterns from both middle-aged and young drivers. Despite similar overall crash rates, the characteristics of young and older drivers' crashes are dissimilar. One of the main differences is temporal. While younger drivers have very high nighttime crash rates, older drivers' evening rates, are only moderately elevated, being much less than drivers under age 25 (Massie & Williams, 1995) (See Figure 6). This difference is even greater when these nighttime crash rates are compared to the groups' respective daytime crash rates. It has been consistently found that older drivers' ratio of nighttime to daytime per-km crash rates is almost 1. One study found that the elderly's accident rates during the nonrush night period "are at the same level during the other time periods, which indicates that their involvement to exposure ratio remains the same in this period as in the rest of the day" (Stamatiadis, 1996). Another national study showed similar results, with more precision. Overall day and night rates converge as early as age 45, and for older groups (above age 65, but peaking between 70 and 74), the daytime rate exceeds the nighttime rate (The slight difference in results between the studies may be the result of different definitions of night. Massie included the hours of 9pm – 6am, while Stramatiadis used the hours of 7pm-7am). This pattern also holds for injury crashes, with older drivers having similar day and night incident rates (Massie et al., 1996).

For drivers of all ages, the gap between daytime and nighttime fatality crash rates is greater than the difference for injury crash rates. Although a gap does remain between daytime and nighttime fatality crash rates, it decreases significantly with age, leveling off around age 45 (see Figure 10).

In terms of magnitude, drivers aged 20-24, had a nighttime to daytime fatality crash ratio of 6.1, representing one of the highest ratios. In contrast, for drivers over age 74, the daytime to nighttime fatality crash ratio is 1.1. These patterns have been duplicated in more recent research (see, for example, Williams & Shabanova, 2003). One exception to this low nighttime rate, is that older drivers have elevated nighttime risks during the very late night (12-6am). This risk is surprisingly gendered, with women's late night to day fatality ratio being 2.6 and men's being 6.8 or approximately 2.6 times greater (Mortimer & Fell, 1989). The reasons for this phenomenon are unclear, because alcohol and risky driving are a minor factor for older male drivers. Despite this anomaly, older drivers' crashes follow a strong pattern that diverges from the younger population: their crashes of all types occur most often during the day, whether measured annually or per km (Cooper, 1990; McGwin & Brown., 1999).

2.1.3.3.3 Behavioural and physiological factors

There are several reasons why older drivers exhibit crash patterns so distinct from those of young and middle-aged drivers. One of the main influences on older drivers' crashes is their driving behaviour. In comparison to younger drivers, older drivers exhibit much less risky driving behaviour. As Li, Shahpar, & Grabowski (2001) conclude from FARS and NPTS data, older drivers have higher belt use rates, more frequently obey speed limits and travel at lower speeds. It is also well documented that, in comparison to young drivers, older drivers' crashes rarely involve alcohol. This is a particular difference in fatal crashes. For example, in 1983, only 12% of drivers over age 65 involved in fatal crashes had any alcohol in their blood. For drivers aged 16-24, this was true for 46%. For drivers aged 25-64, only 64% had a 0% alcohol level (Mortimer & Fell, 1989). This risk avoidance contrasts sharply with younger drivers' behaviour.

In addition to employing these cautious behaviours while on the road, older drivers adjust their travel behaviour to avoid unsafe conditions (Transportation Research Board, 1988, Chapter 2). This includes avoiding poor weather conditions and unsafe routes (Rothe, 1990). Another type of risk avoidance is minimizing nighttime travel (Hakamies-Blomqvist, 1998), in order to avoid driving in darkness and headlight glare (Sivak, 1995). Although this lower ratio of night to day time travel could simply reflect a lesser need for nighttime travel (Hakamies-Blomqvist, 1998), older drivers themselves report avoiding difficult driving conditions, including peak travel times as well as night driving (Wang 2001; Lefrancois and D'Amours 1997). When older drivers do drive at high risk time, such as nighttime, in comparison to younger drivers, they do not compound the danger with other risky behaviours, such as speeding and alcohol use (Stutts & Martell, 1992).

Another major influence on older drivers' crash patterns is physiological. It is widely believed that older drivers have physiological impairments that cause them to crash more often. There is extensive empirical evidence for this belief. Older drivers more often suffer from chronic conditions, such as hypoglycemic attacks (Sturner and Sullivan, 1983) and neurological conditions such as Alzheimer's disease (Hunt el al., 1993), which may impair driving. They also take more medications, which may have dangerous side effects (Ray, Gurwitz, Decker, & Kennedy, 1992). All of these conditions have the potential to result in loss of control of a vehicle.

In addition to these more dramatic cases, aging often results in more mundane functional impairments. One of the most obvious is deterioration in vision (Sivak, 1995), "including slower recovery from glare, slower eye movements, reductions in visual field, visual acuity, and contrast sensitivity" (Keall & Frith, 2004). Another common degeneration is reaction time, with older drivers needing more time both to initiate and to execute movements (Stelmach & Nahom, 1992). Older drivers also have more difficulty extracting information from the environment, require more information on which to base decisions and more often respond inappropriately to driving 'threats' or surprise events (Cooper, 1990).

These conditions and impairments have been shown to affect older drivers' driving safety. For example, Eberhard's 1996 study of U.S. drivers found that one of the major causes of older driver crashes was slowed perception. More recently, Keall and Frith's (2004) data shows that drivers over 70 years are disproportionately involved in crashes as a result of conditions associated with aging. For example, 36% of older drivers' injury crashes resulted from failing to give way, compared to 17% of injury crashes overall. Similarly, 16% of their crashes resulted from failing to see another road user, versus 8% overall. Even more extreme, 15% of their crashes were caused by medical or health reasons, compared to 2% overall. To some degree, these physiological impairments counteract older drivers' safer driving habits, resulting in higher crash rates.

2.1.3.3.3.1 Fragility

One of the least publicly considered reasons for the older drivers' high crash rates is simply that older drivers are more fragile. It is possible that their appearance in police-reported crash statistics is not or is not solely a result of a tendency to crash more, but instead reflects a tendency to be injured or killed as a result of a crash. This would explain some of the peculiarities of older drivers' crash patterns. Despite involving less risk-taking behaviour, older drivers' crashes more often result in serious injuries or fatalities. The proportion of property-damage-only crashes is consistent across all age groups, at about 70% of crashes (Ryan et al., 1998). However, for older drivers, an increasing percentage of the remaining crashes involve a fatality or an injury requiring hospitalization. For example, around 1.6% of middle-aged drivers' crashes involve hospitalization, while 4.4% of over-80 drivers' crashes require hospitalization (Ryan et al., 1998). As older drivers do not drive much at night, are rarely under the influence of alcohol, and speed less than younger drivers, it is surprising that their crashes are more serious. It thus seems probable that physiological, rather than behavioural, factors are influencing their crash rates.

Research on elderly crash victims supports this hypothesis. As Li and others (2001) point out, the elderly are prone to several types of serious injuries, including fractures and chest injuries (Augenstein, 2001; Cavanaugh and Koh, 2001; Wang, 2001; Zhou et al., 1996; Hall and Owings, 2000) and injuries related to seat belts (Augenstein, 2001; Cavanaugh and Koh, 2001; Zhou et al., 1996). In addition, for comparable injuries, older crash victims tend to have a poorer prognosis (Barancik et al., 1986; Waller et al., 1986; Evans, 1988; Evans and Gerrish, 2001; Kim, Nitz, Richardson, & Li., 1995).

Traffic researchers have more directly addressed the impact of fragility on collisions and attempted to quantify its effect. One of the most precise studies of the effects of age on crash outcomes studied the fatality rates of different age groups through examining fatality rates for drivers and passengers in comparable crashes. The crashes' comparability was established by comparing the fatality rates for drivers and passengers in crashes which involved drivers and passengers of a standardized age.[2] The study found that the fatality risk decreases until age 20, when it increases by 2.5% per year for males and 2.16% per year for females (Evans 2004). While this relationship is likely not exactly linear, this does give some idea of the magnitude of fragility's effect on fatal crash rates. For example, Evans suggests that "if populations of 70-year-old males and 20-year-old males are subjected to identical mixes of blunt trauma insults, the population of older males will sustain 250% more fatalities. A population of 70 year-old females will sustain 190% more fatalities than a population 20-year-old females (290% more than a population of 20-year-old males)."

Other studies have given more attention to the shape of the fragility curve. These studies have been simpler, generally employing a ratio of injury and fatal crashes to fatal crashes for drivers of different ages. Two of these studies, by Li and others (2003) and by Keall and Frith (2004) found similar results to the more complex studies. Although fragility increases steadily with advancing age (Li., et al., 2003), it is generally considered negligible until around age 60. The increase is gradual until age 80, when it sharply rises (Li et al., 2003). Although fragility itself increases with age, it contribution to older drivers' crash risk is actually highest for the youngest seniors. Overall, fragility accounts for between 60 and 90% of elderly drivers' excess

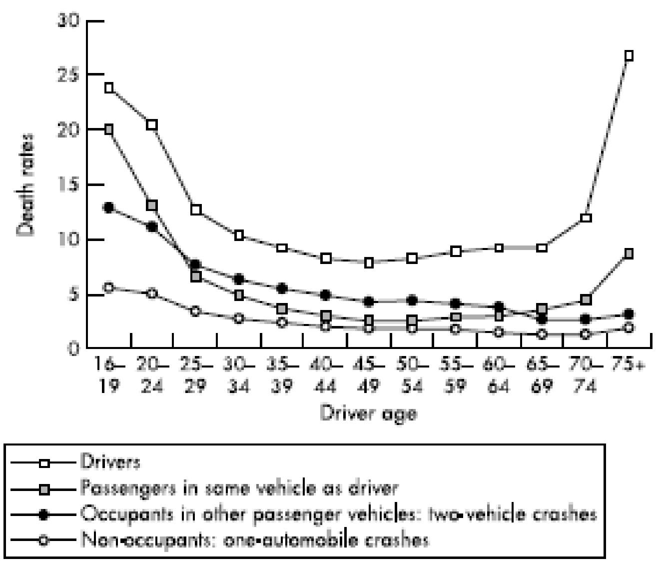
[2] See Evans & Gerrish (2001) for a description of the method.

fatality rates per VMT in older drivers (Li et al., 2003). However, for drivers over 75, it explains only about 30-45% of their excess fatality risk (Li et al., 2003; Keall and Frith, (2004). For the very old, crash over-involvement is the main risk factor, although fragility is still important. The upshot is that older drivers' high crash rates may be largely due to their tendency to be injured or killed in a crash, rather than to be in crashes that are objectively more serious or more frequent. Fragility also contributes to over-reporting of older drivers' crash rates because main crash databases' reliance on police reports bias accident records toward crashes involving fatalities or serious injuries. As more of elderly drivers' crashes result in serious injuries, their overall injury rates are likely over-reported in comparison to younger drivers.

2.1.3.3.4 Risk imposed on other road users

The importance of fragility in explaining older drivers' crash rates is further supported by the low risk that older drivers impose on other road users. It is often thought that seniors are poor drivers who pose high risks to other drivers. Several studies have, in fact, found that older drivers pose less risk to other road users than do younger drivers. For example, Dulisse's 1997 study of Wisconsin drivers found that "the two-unit collisions involving drivers aged 64-74 resulted in fewer deaths and hospitalizations per 100 million miles of driving than did the two-unit collisions of drivers under 65." Although the risk to other road users increases after age 75, it still remains below that for drivers aged 30-65 (Braver & Trempel, 2004).

Figure 11 Deaths per 100 000 drivers by driver age and person type, 1993-97 FARS and 1995 NPTS



Source: Braver, E.R. & Trempel, R.E.. (2004) Are older drivers actually at higher risk of involvement in collisions resulting in deaths or non-fatal injuries among their passengers and other road users? Injury Prevention. 10, 27-32

When deaths do occur they, as discussed above, they are often those of the elderly drivers themselves (see Figure 11). A second elevated risk is to elderly drivers' passengers (See Figure 11), who "incur 2.5 times the number of deaths and 40% more hospitalizations than the persons colliding with older drivers" (Dulisse, 1997).

As most elderly drivers' passengers are also elderly (Braver & Trempel, 2004), this phenomenon is likely also due to increased fragility. Overall, on a per kilometer basis, although elderly drivers have high crash rates, they pose a negative excess risk to other road users. This means that when elderly drivers crash, they tend to disproportionately injure themselves and their elderly passengers, but not occupants of other vehicles. As a result, their high crash rates give an exaggerated picture of their impact on total crash costs.

2.1.3.3.5 Overall (annual) risk

Overall, older drivers are a diverse group. Generally, age 75 is a key threshold, with the total number and the severity of crashes increasing after this point. Regardless, older drivers, as a group, have per-km property damage crash rates similar to younger drivers, but higher injury and fatality rates. These injuries and fatalities primarily affect older drivers and their elderly passengers. This means that their crashes impose less externalities on other road users, but they may still be a public health concern.

What these elevated and complex crash rates obscure, however, is the fact that older drivers' accidents are low in terms of absolute numbers. There are fewer older drivers and they have low average annual mileages. For example, adults over age 75 have less than half the licensure rate of adults aged 30-39 and, on average, drive one third their annual distance (see Table 4).

Table 4 Percent licensed and average annual passenger vehicle miles driven per license holder, by age group, 1983

Image removed due to copyright

Source: Williams, Allan F. & Oliver Carsten. (1989). Driver Age and Crash Involvement. American Journal of Public Health; 79:326-327.

Because of these low licensure rates and low mileage, elderly adults are involved in few crashes annually. For example, an Australian study found that only 3% of crashes involve drivers over 70 years (compared to 35% of crashes involving drivers under age 25) (Ryan et al., 1998). Annually, 5.7 times more crashes involve adolescent drivers than drivers over age 74. Despite the elderly's fragility, very few fatal crashes involve elderly drivers (see Figure 12). Annually, 2.8 times more fatal crashes involve adolescent drivers than the very old (Massie & Williams, 1995).

Figure 12 Number of drivers in fatal crashes by age group, United States, 1983

Image removed due to copyright

Source: Williams, Allan F. & Carsten, Oliver (1989). Driver age and crash involvement. American Journal of Public Health; 79:326-327.

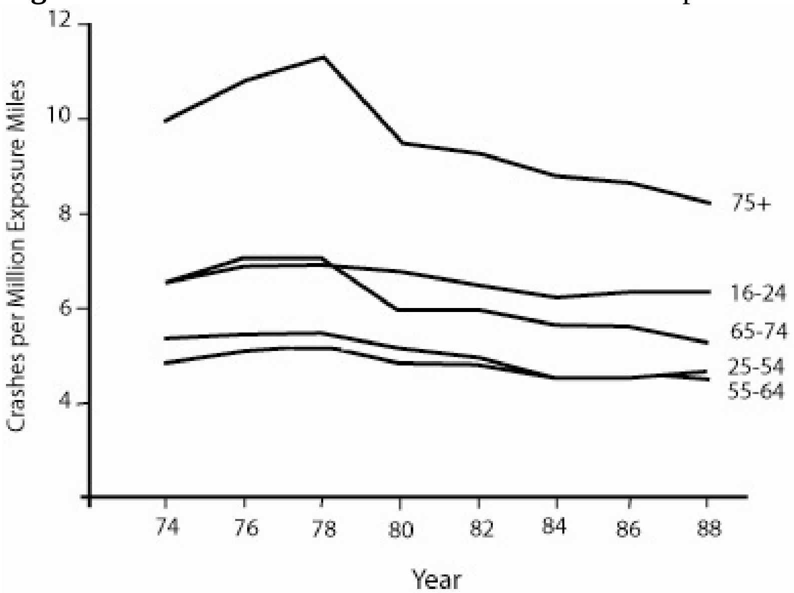
This low absolute number of crashes should be kept in perspective when designing any insurance system.

2.1.3.3.6 Future trends

While older drivers are currently involved in a small percentage of accidents, there is concern about the implications of an aging population for vehicle crashes. The main concern is that the proportion of the elderly in relation to the total population is growing. The projected increase is significant. In 1996, 12.8% of the U.S. population was over age 65. This is expected to almost double, to 22%, by the year 2030 (McGwin & Brown, 1999). A second shift is in older drivers' licensure rates, which have been increasing in the last half century. In 1963, the licensure rate for those over 65 was 63%. In 1995 it was 75%. Rates for those over 70 increased from 56% in 1983 to 70% in 1995 (Lyman et al., 2007). This is likely due to a combination of older drivers retaining their licenses longer and more recent cohorts of elderly drivers having more female drivers (McGwin & Brown, 1999). Despite these previous large increases, however, licensure rates have been stable between the late nineties and the present (Lyman et al., 2002). Another factor in older drivers' accident rates is an increase in older drivers' mileage. While average annual mileage for all drivers increased by 25% between 1983 and 1995, seniors' annual mileage increased by 44% (Lyman et al., 2002). This substantial increase in VMT carries a large increase in risk.

On the other hand, older drivers' per-km and annual crash risk is declining. A North Carolina study showed that although per-km crash rates have decreased for all age groups, the decline was largest for drivers over age 65. As a result of this, older drivers were the only group to experience decreasing annual crash rates, as their per-km crash decrease outweighed their mileage increase (Stutts & Martell, 1992).

Figure 13 North Carolina motor vehicle crashes per million exposure miles, by age



Source: Stutts, J.C., & Martell, C. (1992). Older driver population and crash involvement trends, 1974-1988. *Accident Analysis and Prevention*. *24(4)*, 317-27.

A similar pattern has been shown for fatal crash rates. Li and others' long-range analysis has found a decline in fatal crash rates for each successive generation of older drivers (Li et al., 2001). Similarly, Lyman and others (2002) have noted a 20% decline in per-km fatal crash rates for drivers aged 75 and older and a more than 30% decline for younger seniors, aged 65-74, between 1983 and 1995. This is a large decrease within only a ten year period. In addition, it seems reasonable to assume that the likely causes of this decline, such as healthier older drivers, better vehicle technology and more experienced older drivers, particularly female drivers, will continue to grow, although perhaps not at the same rate. These trends towards safer older drivers may counteract the increase in their numbers.

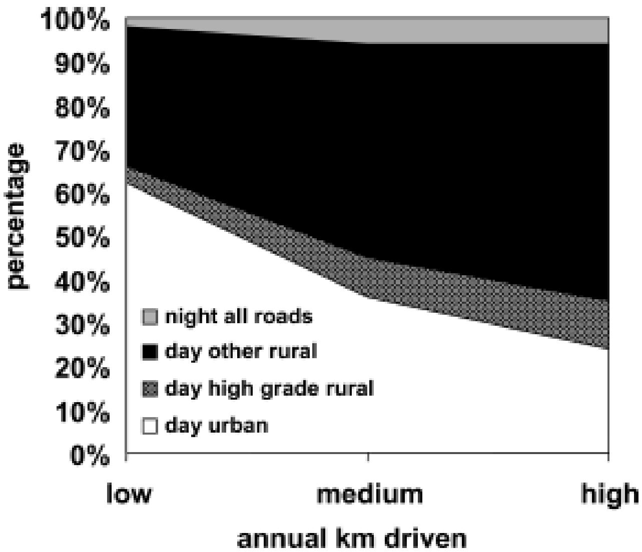
Projections of future older drivers' crash risks depend upon assumptions about the trends of these influences on crash rates. However, estimates generally project very small total crash increases in the short-term and only moderate increases over the longer-term. For example, Lyman and others (2007) predict that older drivers' percentage of contribution to fatal crashes would rise only 1% between 1999 and 2010, from 14 to 15%. They predicted it to rise significantly more over a forty-year period, to 25% in 2030. They expect a somewhat smaller increase in older drivers' contribution to all police reported crashes, rising from 8% in 1999 to 16% in 2030. Although these increases seem large, they still represent a small risk from older drivers, compared to the rest of the population; fairly far into the future; "the bulk of the crash problem will continue to reside with drivers younger than age 65, and particularly with the youngest drivers" (Williams & Carsten, 1989).

2.1.3.3.7 Low mileage bias

Low mileage bias refers to the hypothesis that drivers who have lower annual mileages have a higher per-km risk than other driver because they tend to drive a higher percentage of their mileage in riskier conditions. There are, however, two distinct phenomena which can be encompassed by the concept of low mileage bias.

The first is the simple observation that drivers who drive less kilometers drive more of them in higher risk situations. This primarily manifests itself geographically; low mileage motorists drive more on urban roads and less on highways (see Figure 13).

Figure 14 Percentage of distance driven by drivers aged 65+ with low, medium or high annual km on specified road types and times of day



Source: Keall, Michael D., & Frith, William J. (2006). Characteristics and risks of drivers with low annual distance driven. Traffic Injury Prevention. 7(3), 248-55.

Although this trend is well supported by research, studies on the subject usually use the NPTS, aggregated at a national level. This is problematic because part of the bias is likely due to place of residence (urban or rural) and main purpose of auto ownership (ex. commute or pleasure). Therefore, the different per-km risk should already be addressed by current insurance classes, which charge high premiums to drivers who live in risky, high traffic-density areas. These annual rates can be converted to per-km rates, thereby continuing to account for low mileage bias. Despite this, it is still unclear whether low mileage bias also applies to drivers within the same class. There is no research on whether higher mileage drivers in the same class drive more of these miles on lower risk roads. This pattern is a possibility. For example, an urban driver who takes a summer road trip could accumulate many lower risk highway miles than the average urban commute. However, it is not possible to quantify this effect given the available data. Regardless, if this pattern exists, there are already cross-subsidies between drivers. A distance based insurance program would therefore not be introducing a cross-subsidy into a perfectly accurate and fair system.

A second type of low mileage bias applies specifically to elderly drivers. It has been argued the category of ‘older drivers’ is actually an aggregation of two distinct groups of drivers. The first group is that of healthy and high functioning seniors who drive similar distances and in similar conditions as middle-aged drivers. These drivers have crash risks comparable to middle-aged drivers. The second group is that of unwell seniors who drive very few kilometers per year and who have very high per-km crash rates. It has been hypothesized that these latter drivers consciously restrict their driving to essential trips because they know that their abilities are deteriorating. This hypothesis is supported by a New Zealand study (Koppel et al., 2005) which measured the performance of low and high mileage seniors on driver screening and relicensing tests. Low mileage seniors performed significantly worse than high mileage seniors on these tests. In this case, the threshold for low mileage was very low – less than 50km/week

(2600km/year) in the previous year. This group accounts for only 10% of older driver crashes and for 1% of total annual crashes (Keall, 2001). Therefore, while a low mileage effect does seem to exist for older drivers, it is a very small contributor to total vehicle crashes.

3 PROPOSAL FOR A DISTANCE BASED INSURANCE PROGRAM

3.1 Introduction

As has been discussed, accident risk is unevenly distributed across the population and across different roads under varying conditions. Additionally, different risk factors, such as time of day and age, interact in complex ways. Any vehicle insurance system, including a distance based program, will address these risks differently. Each scheme will have distinct effects on equity and fairness by creating different cross-subsidies amongdrivers. In addition, each model will have different impacts on public health and collision costs, through their pricing of risky driving. They will also have varying implementation costs and impacts on motorists' privacy. Because of these complexities, a full comparison of the options is necessary. This section will compare a recommended distance based pricing scheme – flat-rate pricing, in which individual drivers are assessed a single per-km fee which applies to every km they drive – to the current annual system as well as to alternative distance based insurance models. These other distance based insurance models include three main types of variable pricing: differential pricing, temporal and/or spatial pricing and demographic pricing.

3.2 The status quo: the annual premium system and risk, actuarial accuracy, and equity

In order to evaluate how different types of distance based insurance would address risk and actuarially accuracy, it is necessary to understand how these factors are incorporated into the current system. Although vehicle insurance in British Columbia is required to be actuarially accurate, the annual premium system unevenly addresses major categories of risk.

Temporal and road type risk is very crudely accounted for by the annual insurance system, which has no way to charge drivers according to their individual driving patterns. Despite this limitation, the residential location component of insurance rate classes does provide a crude proxy for these types of risk, particularly that of road type. Individual drivers are charged according to the average annual accident risk of drivers in their geographic area. This accident risk partially depends on the driving conditions under which the average motorist in that area drives. This system increases geographic fairness, but poorly accounts for individual motorists' risk and offers them little incentive to decrease high risk mileage.

Despite the well-known differences in accident risk among different demographic groups, ICBC does not incorporate these factors into its pricing system. Some less influential demographic categories, such as gender and marital status, would have a minimal impact on fees. On the other hand, the exclusion of age, which embodies striking variations in risk, might be thought to raise issues of accuracy and of fairness. For example, both young and older drivers have elevated per-km risks which are not formally accounted for by the current annual pricing system.

However, a fortunate relationship between age, risk and mileage means that an annual system can somewhat address these factors. Essentially, both older drivers and young drivers tend to have high per-km crash risks, although not to the exact same degree. Conveniently, both groups also have low average annual mileages. These groups' low annual mileages balance out their high per-km risk, resulting in an annual risk that is comparable to that of middle-aged drivers. In this way, the annual system works fairly well in ensuring that high risk groups pay fees that approximate their annual crash risk.

In addition to these high risk, low mileage groups – youth and seniors – there is also a group of low mileage, middle-aged drivers. As discussed earlier, this group has a moderately higher per-km risk than the average for middle-aged drivers. This is because these motorists tend to drive a higher percentage of their mileage in higher risk situations, such as during peak hours on urban roads. However, unlike for young and older drivers, these risky travel patterns are not disproportionately combined with other risk factors, such as medical conditions or risky behaviour. The result is that many of these lower-mileage drivers do not have excessively elevated annual risks. ICBC's annual insurance system deals with these drivers by offering discounted rate classes: pleasure, commute to park-and-ride, and commute under 1,500km. These rate classes, however, charge fees almost as high as for the commute over 1,500km class. If a middle-aged driver's mileage is very low, they may still be far below the average annual risk, making their annual premiums unfairly high. It is true that some of these low mileage drivers disproportionately driving in congested urban conditions, resulting in slightly higher per-km crash rates. Howver, drivers are already charged by residential location, which is a proxy for traffic density and thus crash risk. Therefore, urban, low mileage drivers are already paying for some of the risk associated with low mileage driving. This means that many low mileage drivers, who pay rates comparable to high mileage drivers, are the annual insurance system's biggest losers.

ICBC's rate setting processes are mostly invisible to the public. Although ICBC is a crown corporation, insurance pricing is rarely raised as an issue for public debate. Demographic and geographic influences on crash risk are not publicized, either by ICBC or by transportation researchers. Furthermore, a quote for an insurance policy is available only from an Autoplan broker, ensuring that individuals cannot easily compare their own rates against motorists with different mileages, rate classes or residential location. As a result, the insurance pricing system's impact on fairness, equity and driving behaviour is obscured.

Any shift in the insurance pricing will necessitate a discussion of these issues. All insurance pricing systems create some cross-subsidies between rate classes. However, each system's subsidy patterns have different unique implications, particularly for fairness and for equity. One of these key subsidies is between different age groups. The current annual system creates minimal cross-subsidies between age groups, although young drivers are likely moderately subsidized. A distance based system, if it excluded demographic pricing, would likely create some additional cross-subsidies, although their magnitude and direction depends upon the exact program design. For example, various combinations of temporal, road-type and demographic pricing would all price risk differently, thereby creating distinct cross-subsidies. Therefore, introducing distance based insurance will necessitate a discussion of how the vehicle insurance system should treat different demographic group's collision risk and insurance fees.

3.3 Options for distance based insurance

A number of variations on distance based pricing have been discussed in BC. In addition to a simple per-km fee, proposals have included any combination of temporal, road-type and demographic pricing. In all of these systems, per-km rates would vary either according to the driver or the driving conditions. To recap, the major proposals are:

- Differential Pricing
- Flat-rate Pricing
- Temporal Pricing
- Spatial/Road Type Pricing
- Demographic Pricing

Details of these pricing schemes can be found in Section 1.4.6.

3.4 Proposal for a distance based insurance scheme

Although all of the current proposals have merit, the one best equipped to balance effectiveness, efficiency and equity is the simplest type of pricing system: a flat, per-km rate. The fee would not include temporal (time-of-day) or spatial (road type) pricing; all of an individual drivers' kilometers would be charged at the same rate. Consistent with current rates, there would be no demographic pricing, such as variable rates depending on age, gender or marital status. The fee would, however, incorporate most of the current actuarial categories, such as residential location and type of car. One exception is that the rate class for vehicle use (ex. commute, pleasure, commute to park and ride) would be eliminated. As these categories are a proxy for mileage, they would be redundant under a distance based program. Essentially, drivers would be charged a per-km fee that is approximately equal to their current annual fee divided by the average mileage of drivers in their current rate class.

A flat-rate, per-km fee is not a perfect solution. However, compared to both the annual premium system and proposed variable per-km systems, it best balances a number of public policy goals. These include maintaining actuarial accuracy, reducing collisions, protecting privacy, minimizing administrative costs, and improving fairness and equity.

3.5 Comparison of variable and flat per-km fee structures

In considering options for distance based insurance, it is first necessary to consider how different pricing schemes would meet major planning goals. In this case, major considerations are the pricing system's ability to reduce greenhouse gas (GHG) emissions and road and parking congestion. There are also concerns particular to ICBC and its customers. These include preserving drivers' privacy and maintaining the insurance system's simplicity and cost-effectiveness. No one scheme is likely to maximize all of these goals, and all must be balanced in determining the preferred system.

A second major consideration is that any change in insurance pricing will change the insurance system's cross-subsidies between actuarial groups. This is important for two reasons. First, this can affect actuarial accuracy, which has legal implications for ICBC. No system which is perceived as inaccurate by the B.C. Utilities Commission could be implemented in BC. The issue of cross-subsidies, from a planning perspective, also has significant implications for fairness and equity. Although distance based insurance, in general, should be generally economically progressive, it is difficult to ascertain precisely how different systems would affect socio-economic groups. However, what is clear is that any type of distance based pricing, including the decision to price or not to price by time of day, road type or demographic group, would impact different age groups. As inter-age equity and fairness is also a planning issue, these impacts must be also taken into consideration when designing a distance based fee.

Differential, pricing, temporal/spatial pricing and demographic pricing have impacts on all of these planning goals. These types of pricing can be combined, further complicating the issue. Despite this overlap, temporal/spatial pricing has the largest effect on goals such as GHG and congestion reduction. Demographic pricing, whether used alone or combined with temporal/spatial pricing, has the largest actuarial accuracy, fairness and equity implications. For simplicity, each pricing system and its primary effects will be discussed separately. Two issues, actuarial accuracy and revenue neutrality, are common to all proposed systems and therefore will be discussed first.

3.5.1 Actuarial accuracy and revenue neutrality

One of ICBC's main concerns about distance based insurance is its ability to preserve actuarial accuracy and revenue neutrality. The company is required to demonstrate to the BC Utilities Commission that any proposed rate changes are actuarially accurate. In reality, perfect actuarial accuracy will always be elusive, due to limited information and to complex pricing systems' logistical costs. However, changes to insurance fees should embody the spirit of actuarial accuracy and should not reduce accuracy over the current system. In addition to this requirement, as a crown corporation, ICBC is mandated to provide auto insurance to BC residents without provincial subsidy. Therefore, in order to be acceptable, a distance based insurance system must theoretically be revenue neutral and actuarially accurate. A flat per-km fee must, at a minimum, pass this test in order to be feasible.

It is sometimes assumed that various model of differential pricing are more actuarially accurate than simpler systems. This is untrue. A flat, per-km system is not necessarily as precise as one that incorporates temporal and spatial data. However, it is not necessarily less accurate than temporal or spatial pricing, and there is no reason that it can not be at least as accurate and precise as the current annual system. Individual insurance companies providing standard annual policies employ a variety of actual categories. Both the number of categories and their criteria are mutable, varying across jurisdictions and between companies. For example, martial status has sometimes been employed as a rating factor in the auto insurance industry, but is not currently used in British Columbia. The exclusion of this type of criteria does not make insurance pricing inaccurate. As long as a rate class produces predicable annual costs, it can be considered accurate. The proposed per-km system makes few modifications to ICBC's current rate classes. Therefore, the correct rates to cover future claims costs for each actuarial group should be relatively easy to calculate. Although there may be a trial period for refining the system, there is no reason to expect that proper rates cannot be determined. The upshot of this is that any type of per-km pricing system, whether flat or variable, can be considered accurate and can be made revenue neutral.

3.6 Differential pricing

Differential pricing refers to various methods of pricing which are aim to improve actuarial accuracy by compensating for low mileage bias. For example, it would be possible to price initial kilometers at a higher rate or to charge low mileage drivers a higher per-km fee. This section will speak broadly about these proposal, rather than evaluating one particular scheme.

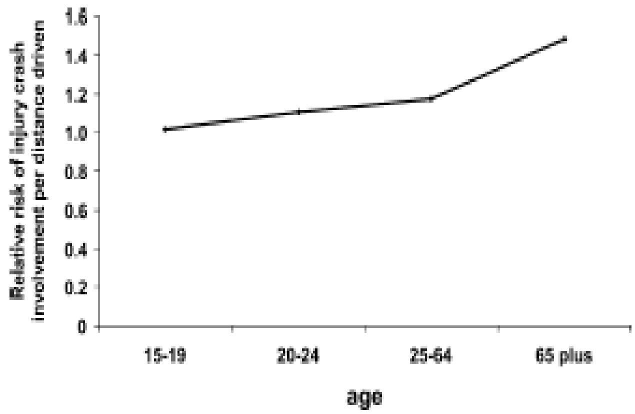
3.6.1 Fairness

As discussed in Section 1, a distance based model can be at least as equitable and as fair as the current system. The most basic principle of distance based insurance, that drivers pay for their own mileage, is an example of the user-pays principle of fairness. Despite this general truth, distance based insurance might create some other, possibly unfair, cross-subsidies between motorists.

3.6.2 Low mileage bias

The main issue of fairness is related to actuarial accuracy and to low mileage bias. Because low mileage drivers tend to have elevated per-km accident rates, a distance based system will arguably undercharge low mileage drivers and overcharge high mileage drivers, in relation to their accident risk. However, the magnitude of this effect is very small. For young drivers, there is no difference in per-km risk for low and high mileage drivers. For drivers under the age of 65, low mileage drivers have a higher per-km risk somewhere in the order of ten to fifteen percent. Even for older drivers, the group which displays the largest effect of low mileage bias, the increased risk for low mileage drivers ranges between fifteen and fifty percent, compared to drivers of the same age (Keall & Frith, 2006). While this may seem high, it must be put into perspective of the variation in accident risk. For example, young male drivers have per-km injury crash risks five times higher than that of the middle-aged population. In comparison to this high risk differential, a fifty percent increase in crash risk is minor. Moreover, for drivers under age 65, middle-aged, low mileage drivers' elevated risk is far closer to the bottom end of the range (see Figure 14). In addition, low mileage drivers' elevated risk is likely attributable to their high mileage in urban, traffic-dense conditions. Including current geographic rating factors into a flat-rate system would already partially compensate for low mileage bias by charging urban residents a higher per-km rate.

Figure 15 Relative risk (of injury crash involvement per distance driven) at low annual km driving patterns compared to risk at high annual km driving patterns, by age



Source: Keall, Michael D., & Frith, William J. (2006). Characteristics and risks of drivers with low annual distance driven. *Traffic Injury Prevention*. *7*, 248-55.

The upshot of this is that a flat per-km charge will slightly undercharge most low mileage drivers and moderately undercharge elderly low mileage drivers. On the other hand, a flat per-km charge, which does not include demographic pricing, would overcharge low mileage young drivers. Accounting for even this basic difference in risk categories would result in a fair degree of complexity. It would also require changing the law prohibiting ICBC from employing demographic pricing.

Ultimately, there is a limit to the precision of any pricing system. The current annual insurance fee is, in comparison even to a flat per-km fee, very imprecise. Its overcharge of low mileage drivers can be a large percentage of the total policy fee if a vehicle is rarely driven. Therefore, even a flat per-km fee will increase fee's precision. It is possible to increase this precision further through a differential per-km fee. For example, ICBC could charge a higher rate for the first 3000km driven. However, providing additional miles at a reduced cost is contrary to the point of a distance based system, which is to increase the marginal cost of driving. Moreover, the possible precision gain would entail trade-offs in administrative cost, effectiveness and popularity. These costs do not seem justified by the small differences risk differences between low and high mileage drivers.

3.6.3 Equity

The issue of equity is partially independent of the issue of fairness. Its major concern is related to the distribution of mileage throughout the population, with low mileage bias being of lesser importance. As has been discussed, there is a strong positive correlation between household income and vehicle mileage. As a result, the annual insurance system represents a subsidy flowing from lower-income to higher-income households. A per-km system, by eliminating this subsidy, would increase equity. This broad picture is true regardless of the detailed design of the per-km fee.

Although it is of lesser importance, it should be pointed out that a flat per-km fee would be more equitable, although slightly less fair, than any type of differential pricing. In addition to driving less on average, low-income individuals are concentrated in the category of low mileage drivers (less than 3,000miles/year or about one quarter of the average annual mileage). This pattern is consistent across all age groups. For example, Keall and Frith (2006) found that fifty-seven percent of middle-aged, low mileage drivers were low-income, compared to fourteen percent of high mileage drivers. For seniors, 83% of low mileage drivers were low income, compared to fifty-nine percent of high mileage drivers. Because of this, the small subsidy given by a flat per-km system to low mileage drivers would disproportionately benefit low-income individuals. A differential pricing system, if it increased fairness, would do so at the expense of equity. Either a flat-rate or a variable-rate per-km system is superior to the annual system which is both unfair and inequitable. A differential per-km fee system, however, can increase fairness only at the expense of other goals, such as effectiveness. A flat per-km rate can increase equity without these other drawbacks. Therefore, while both programs have advantages, a flat per-km fee should result in more overall benefits and achieve more planning goals.

3.6.3.1 Differential pricing summary

Differential pricing would, to some degree, improve a distance based pricing system's ability to compensate for low mileage bias. Although a flat-rate system is not inaccurate, it would create a subsidy from high-mileage to low mileage drivers. However, the magnitude of this subsidy is very small. Non-elderly low mileage drivers have a very small elevated risk compared to high-mileage drivers of the same age. In addition, this elevated risk would be partially accounted for by current geographic rating factors, which could charge a higher per-km rate for residents of high traffic-density areas. Ultimately, the small magnitude of low mileage bias does not seem to justify a pricing system tailored to compensate for it.

In addition, a differential pricing system could only account for low mileage bias at the expense of other planning goals. For example, because low-income drivers tend to have low mileages, increasing the price of initial mileage would decrease distance based insurance's potential for increasing economic equity. Another issue is that differential pricing works against the basic principle of distance based insurance, by reducing the marginal cost of driving. This would limit distance based insurance's potential to reduce emissions and collisions and increase active transportation.

3.6.4 Temporal and spatial pricing

In addition to implementing simple variable pricing to correct for low mileage bias, it is possible to create more complex variable pricing systems that more precisely price risk. For example, it is possible to price per-km insurance by time of day, road type or a combination of these two variables. These types of pricing, in comparison to a flat per-km fee, would have different social, environmental and financial impacts. However, different planning goals entail different trade-offs with each other and against the cost of implementing different insurance pricing schemes. Overall, a flat per-km fee best balances these costs and benefits.

3.6.4.1 Greenhouse gas emissions and ground level air pollution

As discussed in the introduction, any type of distance based insurance program is likely to reduce mileage, thereby decreasing greenhouse gas emissions and ground level air pollution. The issue, then, is how the potential emissions reduction from a flat-rate program compares to that from a more complex pricing system. The main difference between the programs would be their effect on the total number of vehicle starts (ie. total trips) and on these trips' driving conditions, (ex. congested vs free-flowing traffic). It may be possible to design a pricing system that targets trips in congested traffic by charging higher rates for certain roads and during peak hours. Targeting the number or length of trips through any distance based insurance scheme would be considerably more difficult. It is important to consider, however, that incorporating current residential location rating factors into a flat per-km rate would already approximate a higher fee for riskier urban driving. As urban residents currently have higher annual fees, they would have higher per-km fees under the new program. Although a temporal charge would further increase the precision of assessing risk, the magnitude of this effect is unclear. Additionally, a temporal charge would require trade-offs with other public goals and values. This will be discussed in more detail later. Even without considering these trade-offs, however, given the close correlation between mileage and emissions (Stead, 1999), it seems that a large part of the benefits of emissions reduction can be achieved through a second-best pricing scheme that simply reduces total annual mileage.

3.6.4.2 Collisions

A reduction in vehicle collisions is desirable both from both the point of view of improved public health, corresponding reduction in medical care costs from accidents and air pollution exposure, and in terms of reducing ICBC's costs. Similar to the relationship between mileage and emissions, there is a strong correlation between mileage and collisions (Liddell, 1982). As with emissions, it is possible to design a variable per-km pricing system that targets the most risky vehicle trips. However, in comparison to implementing an emissions-focused pricing system, using variable rates to reduce collisions is much more complex.

The first complication for a variable rate scheme is that there is some conflict between emissions-reduction and collision-reduction pricing. In terms of emissions, it is most desirable to reduce urban, peak-hour trips. A complementary benefit to reducing these miles is congestion reduction. Reducing urban, peak-hour trips is also a goal for collision reduction. This type of mileage is considered to be medium-risk (Progressive County Mutual, 2007), as it results in a high number of minor, but costly, injury and property damage collisions. Despite this commonality, the most high risk vehicle miles do not overlap with those producing the most emissions. Overall, nighttime driving is considered riskier than peak-hour trips. In addition, most fatalities, a considerable public health concern, occur at night on rural and minor roads. However, nighttime, rural, driving contributes little to pollution or congestion. As a result, a basic conflict exists between the goals of emissions and collision reduction. A variable pricing scheme can only price either high-emissions or high-collision miles at the highest rate. The necessity for revenue neutrality and actuarial accuracy makes it more likely that high-collision miles will have the highest price. Although this conflict is not an insurmountable barrier to variable per-km rates, it does mean that a variable system will not likely reach its full potential for targeting emissions or congestion.

A second limitation of temporal and spatial pricing is that it entails major trade-offs between accuracy and simplicity and between accuracy and precision. Temporal pricing alone involves dealing with very complex collisions patterns. As has been previously discussed, collision rates vary by time, day and season. One major division is between day and night driving. When all drivers are aggregated, nighttime driving is more risky than daytime driving. Another major distinction is between the weekends and the weekdays. Weekend nights are much riskier than weekday nights. On the other hand, weekend days lack a rush hour, thereby eliminating the medium-risk of driving in congested traffic. Accounting for these basic temporal distinctions alone would result in a complicated pricing structure. An example of this can be seen in Figure 16, which represents a Canadian insurance company (Aviva)'s, temporal system for distance based pricing. This system, which basically distinguishes only between weekdays/weekends, rush-hour/non-rush hour, and day/night results in fourteen price bands. A more precise system would result in even more categories.

Figure 16 Aviva Canada Pricing Structure

Image removed due to copyright

Source: Aviva Canada <www.saveasyoudrive.com/page.asp?pageid=34>.

Although most current distance based insurance programs incorporate only temporal pricing, spatial pricing, based on road type, has also been discussed in the context of a BC program. When spatial risk is combined with temporal risk, the patterns become exceedingly complex. For example, it is well established that nighttime driving is riskier than daytime driving. However, this pattern does not hold for a very common travel behaviour: driving on major urban roads during the week. On weekdays, major roads, which tend to be illuminated and avoided by drunk-drivers, are barely more risky at night than during the day (Keall et al., 2005). A temporal-spatial system would therefore likely require a division between weekend and weekday night driving on major and minor roads. To further complicate this issue, these same major roads are riskier than minor roads during the day, particularly during rush hour. If this single spatial factor was incorporated into pricing, then it could result in Aviva's fourteen categories at least doubling.

Another complication is that these overall temporal and spatial crash patterns are sensitive to demographic differences. One major complication is that the effects of the major temporal distinction, day vs. night driving, varies highly by age. Strikingly, a higher night time crash rate exists only for drivers under age 45. Drivers over 45 have similar night and day rates (Massie et al., 1995), and drivers over age 65 have a lower nighttime than daytime crash rate (Stamatiadis, 1996). Because of this, an age-insensitive variable pricing system could have perverse effects on travel behaviour. For example, if aggregate risks were applied to insurance pricing for the entire population, this would incentivize a large population to reduce their nighttime driving even though they have virtually no elevated risk at this time. In the case of elderly drivers, this system would encourage them to drive at a time that is relatively more dangerous for them. Of course, this is an unavoidable consequence of any aggregate pricing system. However, this case involves a very large group of drivers - all those over age 45 - and thus represents a major obstacle to implementing variable rates. One possible solution is to create different pricing systems for different demographic groups. This would avoid some of the problems discussed here. This option will be addressed in more detail later in the context of different options for demographic pricing.

A final barrier to variable pricing is that some of the major temporal and spatial crash patterns appear to be indirect measures of risky behaviour rather than representing inherently risky driving times. This is most dramatically illustrated by the example of alcohol use. For example, a study of US crashes showed that "the overall effect of alcohol was shown to contribute almost half of weekend night time risk for drivers aged under 40 on lower volume roads (Keall et al., 2005). Therefore, the differential road type risk for night driving may be as much the result of alcohol consumption as of poor lighting and road conditions. For the highest-risk drivers, this effect is even more pronounced, influencing driving on all road types; the same study found that alcohol involvement contributes about half of young male drivers' overall night time risk for summer weekends (Keall et al., 2005). This effect is not limited to alcohol use. Another contributor to night time risk may be general risky driving behaviour, such as speeding and sudden stopping. This conclusion is supported by a survey of teenage drivers that found that a majority of their self-reported dangerous driving occurred at night (Farrow, 1987). The upshot of this is that risky behaviour, perhaps as much as driving conditions or exposure, contributes to temporal and spatial crash patterns. In this case, high nighttime per-km rates may not well address the causes of nighttime crash risk.

Despite these findings, if variable pricing indirectly reduced these risky behaviours, through reducing risky drivers' evening driving, then it would still be worth consideration. However, it is doubtful that this would be the case. Alternatives to driving, such as public transit, are limited at night. This means that nighttime driving may be less responsive to prices than daytime or evening driving. Moreover, drivers who drive drunk or unsafely are doing so despite the strong disincentive of risking a fatal crash. Considering this, it seems unlikely that the relatively weak incentive of a marginal price difference will discourage their nighttime driving. As a result, temporal pricing may reduce nighttime driving of low risk drivers while having little effect on the travel patterns or driving behaviour of the riskiest nighttime drivers. Another program, such as increased enforcement or license restrictions, that directly addresses high risk behaviour or limits the driving of high risk demographic groups may be more effective and have less unintended consequences than a variable insurance pricing system.

3.6.4.3 Psychological aspects of pricing schemes

Even if an insurance pricing scheme could be designed to reflect different demographic groups' distinct temporal and spatial risk patterns, its effectiveness would be constrained by drivers' ability to respond to the pricing incentives. There is good evidence, from both road pricing trials and from other pricing systems, to suggest that more precise, complex systems often do not result in more ideal consumer behaviour than simpler systems. They are also less popular than simple pricing schemes. Some researchers (Bonsall et al 2007) have investigated the implications of psychological research for road pricing. Although they did not directly address insurance pricing, many of the road pricing principles are applicable to this topic. Of particular interest are the goals of effectiveness and public acceptability. These aims should be considered in selecting a distance based pricing scheme.

3.6.4.3.1 Effectiveness

One of the most fundamental influences on a pricing scheme's effectiveness is individuals' capacity to store and process information. Although this capacity varies, it is thought that most people's limit is seven items of number or abstract data at one time (Bonsall et al., 2007). This number suggests the maximum number of pricing bands that could be expected to be effective for any pricing system. However, while people can process seven items of information, this doesn't mean that they will in any given situation. This is because information processing requires mental work and thus represents a transaction cost (Bonsall et al., 2007). In order to avoid mental effort, people will use heuristics – simple forms of thinking. These simplifications neutralize the benefits of a precise system. Heuristic strategies are varied, but include focusing on a subset of an option's attributes or using one variable as a proxy for another. An example of the latter, related to vehicle insurance, is using driving time to predict distance, or vice versa. An example of the former is focusing only on the different cost of nighttime vs daytime driving, while ignoring spatial or road-type pricing.

Driving exemplifies some of the most common conditions in which people use heuristics to avoid transaction costs. People often use heuristics when they are in a hurry and when cost differentials are small. This would likely be the case for many vehicle trips, limiting the effectiveness of temporal and spatial price bands. Temporal and spatial pricing would likely also trigger other types of behaviour. For example, another response to increased complexity and the high transaction cost of decoding it is to stick with the status quo (Bonsall et al., 2007). Even worse, information overload can increase the use of poor heuristics, and decrease the optimality of decision-making (Ariely 2000). Therefore, a more precise pricing system could have the opposite of the desired effect, causing motorists to either maintain their current behaviour or to drive under riskier conditions.

3.6.4.3.2 Public acceptability

Regardless of a how well a pricing system it designed, it can be effective only if it attracts consumers. In addition to a complex pricing systems' limited effectiveness, it may prove very unpopular. In particular, if vehicle insurance is offered as a consumer option, its increasing complexity may decrease its attractiveness in comparison to traditional, annual insurance. This is true for two main reasons. First, people tend to be risk-adverse and thus prefer options with known prices over those whose price is uncertain. This had been consistently demonstrated in many spheres of consumer behaviour, including trials of road pricing (Bonsall et al., 2007). Annual insurance clearly has an advantage over distance based insurance in terms of cost certainty. However, simplifying a distance based system can mitigate this difference. Drivers must know their annual mileage for insurance purposes. Therefore with a flat per-km rate, they can easily estimate their costs under a distance based system. The more complicated are the rates for different mileage conditions, the more uncertain are motorists' annual costs. Therefore, a simpler system, by increasing cost predictability, can improve a distance based program's appeal in comparison to an annual fee.

A second phenomenon that affects different insurance schemes' relative attractiveness is ambiguity avoidance. It has often been observed that people will choose a sub-optimal option if it is the only one which they understand (Bonsall et al., 2007). Being a new option, distance based insurance may be less popular than annual insurance due to its unfamiliarity. Of course, all pricing schemes were new at some time, and consumers are likely to become more comfortable with them over time. However, distance based insurance will not survive in the long-term if it cannot attract consumers initially. Therefore, making distance based insurance as intuitive as possible will be important to its success. A simpler fee system, by virtue of its comprehensibility, will likely raise more consumer interest.

Of course, it is also possible to mandate distance based insurance. However, the implications of product attractiveness do not disappear; they are merely shifted from the context of consumers to that of voters. Therefore, it is just as important to keep insurance fees attractive to ICBC customers if they are mandatory than if they are optional. A flat rate, per-km fee would achieve this better than a variable fee because of its comprehensibility and predictability of costs.

3.6.4.4 Logistical simplicity

Another advantage of a flat, per-km rate over a variable per-km rate is its logistical simplicity. A per-km fee that is temporally and geographically insensitive is easy for people to understand. This should reduce the time needed to explain the system to customers and avoid later confusion and disagreement about fees. This would minimize ICBC's administrative costs.

Another potential savings of this system is the cost of technology. Most private distance based insurance programs collect data through GPS or similar units. This is also a possibility for the distance based program proposed here. However, a flat per-km fee can also be administered through more low-tech options, such as odometer readings. Although the cost of GPS units has fallen in recent years, purchasing, installing and maintaining units is still an expense. It has been estimated that, if odometer readings were conducted in conjunction with yearly vehicle tune-ups, the cost would be only $5-10 (Litman, 2007). Not only is this a minor cost, but its initial and sunk components are very small, thereby minimizing ICBC's financial risk.

3.6.4.5 Privacy

A flat rate system has another advantage over temporal/spatial pricing: maintaining privacy. It is possible for a GPS-like device to record temporal and geographic data without reporting a vehicle's location. This type of system is used by private insurance companies in the United States, England and Ontario. However, ICBC's previous focus groups on this subject suggest that there is a limited market for a per-km program that requires cars to be fitted with any type of tracking device. Therefore, a flat-rate pricing system, with a reporting mechanism like odometer reading, would likely be more publicly acceptable in British Columbia.

3.6.4.6 Summary

Temporal/spatial pricing, like all distance based systems can be revenue neutral and actuarially accurate. In comparison to flat-rate pricing it is more precise. The result of this is that inaccuracy is spread differently over the population. Under a flat-rate system, all drivers are slightly under or overcharged as their rates do not precisely reflect their risk. The precision of a temporal/spatial pricing system has the potential to more accurately charge drivers whose collision patterns are typical of certain times and road conditions. However, the system will also seriously over or undercharge some individual drivers whose driving and collision patterns are atypical of their temporal/spatial patterns. For example, certain driving conditions, such as rural highways or urban side roads, have high nighttime crash risks, primarily due to risky driving. Any motorists who drive cautiously under these conditions will be significantly overcharged for their driving. As temporal/spatial pricing becomes more precise, the magnitude of this over/undercharging will increase. This shifting of the burden of inaccuracy from the collective to individual drivers may be particularly unacceptable to citizens.

One advantage of temporal/spatial pricing is its ability to target certain driving conditions for high pricing. This can not only reduce vehicle trips but can also shift some trips to more desirable times. However, this advantage is limited, because high risk and high emissions conditions are not exactly aligned. As only high emissions or high collision risk conditions can be priced at the highest rate, each of these impacts can only be targeted at the expense of the other (See Table 5). Even a pricing system which balanced these impacts would be limited in its effectiveness of human's ability and desire to respond to complex pricing systems. Because of this, more complex temporal/spatial pricing systems likely have little advantage in reducing externalities over a flat-rate system. The little advantage that they add must also be weighed against the disadvantages of increased administrative costs and reduced privacy. In particular, the loss of privacy resulting from in-vehicle transponders required for temporal/spatial pricing should not be underestimated as a political obstacle to changing insurance pricing. Overcoming this obstacles may require an effort and an expenditure of political capital that is not justified by the small additional benefits provided by a temporal/spatial system.

Table 5 Comparison of temporal/spatial and flat-rate pricing systems

	Impacts					
Pricing Systems	Revenue Neutral & Actuarially Accurate	Fairness	Equity	Emissions Reduction	Collision Reduction	Privacy
Temporal/Spatial Pricing	Yes	Extreme over/under charging of a few drivers	Medium	Potentially high, but at the expense of collision reduction	Potentially high, but at the expense of emissions reduction	Low – requires in-vehicle transponders
Flat-Rate Pricing	Yes	Slight over/under charging of many drivers	High	Medium	Medium	High – requires odometer readings

3.6.5 Demographic pricing

Although demographic pricing is currently used only in a limited way in B.C., it should be considered when discussing any change in the insurance system. There are several reasons for this. First, the lack of official demographic pricing does not negate cross-subsidies between different demographic groups. For example, the current system's lack of demographic pricing overcharges any demographic group which has both below average risk and below average mileages. A major example of this type of subsidy is gender-neutral pricing. Women of all ages, in aggregate, have lower mileages and comparable or lower risk than that of men of the same age. The result is that the annual, gender-neutral system creates a subsidy flowing, in the aggregate, from women to men (Butler, 1996). The National Organization of Women (NOW) considers this to be such an important issues that, since the early 1990s, it has been running a campaign for distance based pricing. A distance based system would correct this particular subsidy, but might create new ones. As different cross-subsidies have different levels of social acceptability, it is important to examine how different distance based systems would affect these subsidies.

When examining these subsidies, it is important to consider both their broad impact and their most extreme cases. Some subsidy systems may be generally more equitable, but create rare, but grossly unfair, burdens on individuals. Both of these impacts are important for fairness as well as for public acceptability and therefore both must carry weight in decision-making.

A second consideration is that certain cross-subsidies may be considered illegal by the B.C. Utilities Commission. Although cross-subsidies are unavoidable, very large ones, even if they are socially desirable, may be considered actuarially inaccurate. Therefore, a basic test for any pricing system is its ability to maintain actuarial accuracy.

3.6.5.1 Actuarial accuracy

One general consideration in evaluating demographic pricing is the relationship between accuracy and precision. The main justification for implementing demographic pricing is a desire to increase insurance pricing's fairness by correctly pricing drivers' risk. However, this argument is based on the assumption that accuracy and precision are directly related. In fact, the opposite is often the case. Increasing precision may, in some cases, decrease accuracy. It is impossible to know for certain any individual driver's accident risk. The actuarial system relies upon using predictive variables to determine rates for groups of drivers. As the number of variables increases and the number of actuarial groups grows, inaccurate risk predictions for individual drivers may be an increasing problem. For example, young, male drivers, in aggregate, have very high crash rates. Therefore, it is actuarially justifiable to charge all young, male drivers a high per-km rate. However, much of this group's accident risk is due to drinking and driving. If an individual young, male driver never drink and drives, then he may be grossly overcharged for insurance.

Of course, inaccurate individual risk assessments always exist in an insurance system. However, the greater the difference between rates for different groups, the greater is the magnitude for over or undercharging individuals. As auto insurance is a large expense for many people, these outlying inaccuracies can have significant consequences for individuals. Therefore, this potential unfairness is an important consideration in choosing a pricing system. A flat rate system may perhaps be less accurate than a variable system at the aggregate level. However, because the range of per-km rates is smaller than under a variable program, there is less potential for any individual driver to be under or over-charged by a large amount. This likely gives flat-rate distance based insurance an advantage of greater perceived fairness, in comparison to other pricing systems.

3.6.5.2 Demographic pricing categories

Although several demographic factors can be used in pricing vehicle insurance, age is the most important. This is because it is both a major predictor of risk and one of the more publicly acceptable types of differentiation. It is also a category of risk which would be treated very differently by annual and distance based pricing systems. The current annual insurance system deals with risk in a simple way. Because high risk demographic groups tend to have lower than average mileages, their annual risk is not substantially higher than average. Therefore, a standard annual premium rate can approximate most drivers' risk. A distance based system would work in a similar way. However, individual drivers and subpopulations of drivers within high risk demographic groups may pay high annual fees if they have high mileages. Therefore, demographic pricing raises complex questions of equity and fairness. The benefits of demographic pricing must thus be weighed against the costs it imposes on certain subpopulations.

3.6.5.2.1 Older drivers – low mileage older drivers

Older drivers, as discussed earlier, can be divided into different subpopulations. The first group is that of the impaired or ill elderly, who are already limiting their mileage. Although this is a relatively high risk group, its travel and crash patterns indicate that it may be very difficult to reduce its travel. Marginal pricing, in particular, may be too weak a mechanism to achieve this result. Studies of elderly drivers have found that those who drive less than 2,500-3,000km/year have elevated per-km crash risks. This threshold is quite low, being around 25-30% of the average annual per-vehicle mileage. It is difficult to know how much pricing would affect the travel behaviour of drivers in this mileage group. However, if it resulted in a distance based insurance program's overall expected reduction of 10%, this would consist of only an annual, per capita reduction of 250km per capita for this population. Even this reduction seems optimistic. As this population has already limited its driving for safety reasons, it seems unlikely that a higher per-km rate would further reduce their mileage. In addition, this high risk population is only a subsection – approximately 10% (Koppel 2005; Langford et al., 2006) - of an already small elderly population. The cost of designing and administering a pricing system around this small group of drivers may not be worth the small potential benefits that could be realized.

It is sometimes suggested that this group of drivers should be targeted for mileage reduction because they impose large costs on other road users. This is a poor justification for age-based pricing. While infirm older drivers do increase other drivers' risk, the magnitude of this risk, on both a per-km and annual basis is likely exaggerated in the public imagination. As discussed previously, although infirm older drivers have high per-km and moderate per-capita crash rates, their total contribution to vehicle collisions is low. This population's crashes are actually a fairly rare occurrence, composing "well under 1% of total road crashes" (Langford et al., 2006). Thus, while these drivers do have a high per-km crash rate, their overall impact on other road users is small.

Furthermore, while older drivers' do crash more often, when they collide with other vehicles, they do not disproportionately injure other road users. Although more of these drivers' crashes are reported as injury or fatality crashes, they are not objectively more serious collisions than average. Instead, they fall into these categories because elderly drivers and their passengers are more easily injured. Although older drivers' excess injuries and deaths do pose higher costs to the insurance system, it seems perverse to charge them a higher rate for the high proportion of their injury risk which is due to their fragility, not to their poor driving. This, combined with their total low impact on other road users, in terms of accident cost and injury, justifies a simplified pricing system that avoids charging older drivers higher rates.

Even if this subpopulation of infirm elderly drivers' mileages could be reduced through insurance pricing, it is questionable whether this is a desirable policy goal. While reducing elderly drivers' crash rates might reduce ICBC's costs, it may not be a desirable from a broader perspective. As infirm older drivers are conscious of their poor driving ability and have reduced their driving to a very small amount, they appear to be making only trips whose value outweighs their higher risk of being injured or killed in an accident. As these drivers are not posing a high annual risk to other road users, it seems reasonable to allow older drivers to make this choice for themselves.

Table 6: Comparison of older driver and demographically neutral pricing

Impacts					
Pricing Systems	Revenue Neutral & Actuarially Accurate	Fairness	Equity	Emissions Reduction	Collision Reduction
Older Driver Pricing	Yes	Significantly overcharges healthy, high-mileage older drivers Infirm older drivers pay for their aggregate risk	Low	Similar to flat rate pricing	Medium -
No Demographic Pricing	Yes	Undercharges infirm older drivers All drivers subsidize infirm older drivers' aggregate risk	High	Similar to flat rate pricing	Medium

Attempting to reduce their remaining trips may be restricting these drivers' basic mobility, particularly in regions which provide few other transportation options. Until alternative transportation options are viable for most BC seniors, attempting to reduce their already low mileage is an unfair restriction of their basic mobility.

3.6.5.2.2 Older Drivers – medium and high mileage drivers

The second major population of older drivers is one whose travel and crash patterns are similar to those of younger drivers. There is no justification for charging this group a higher rate than middle-aged drivers. However, in designing a variable rate system, it would be difficult to separate these drivers from infirm older drivers. Even if this was politically possible, current screening tests are poor at identifying risky older drivers on an individual level (Fain, 2003). As a result, this group of drivers would be the biggest losers in an age-based, per-km premium system. Under this system, high risk older drivers would not likely pay significantly higher rates annually. These drivers tend to have low mileages, which would compensate for their higher rates. However, healthy, lower-risk older drivers tend to drive high mileages, similar to younger drivers. If they were aggregated with the population of high risk older drivers, they would pay higher per-km rates, but pay for many more kilometers (probably around three to five times more than high risk elderly drivers). This system could still be revenue neutral, but it would shift the subsidy of high risk older drivers from the entire driving population to a small group of healthy older drivers. This would create a situation which is unfair and likely runs contrary to public opinion. Currently, ICBC's only legal age-related pricing distinction is for seniors' discounts.

Although the law can, of course, be changed, its existence seems to indicate a public preference for minimizing seniors' costs. This is consistent with the wide acceptance of seniors' discounts for many public and private services. Therefore, age-based, per-km pricing by shifting costs from the general population to a subgroup of seniors, would be inconsistent with current social values. A flat-rate, pre-km system would better maintain mobility for low mileage seniors and maintain affordability and fairness for average-mileage seniors.

3.6.5.3 Young drivers

3.6.5.3.1 Insurance pricing as a risk reduction mechanism

Because the highest risk older drivers have very low mileages, older drivers pose a low overall crash risk. In contrast, many young drivers have both high per-km risk and fairly high annual mileages. However, the high sunk cost of annual premiums currently functions to discourage many youth from driving. This reduces the potentially high impact of young drivers on overall crash rates. In order to maintain this reduction, some proponents of distance based insurance have suggested that young drivers either be excluded from the program or be charged a very high per-km rate. While a high per-km rate, which covers young drivers' actual risk may be warranted, young drivers' exclusion from the program is unjustified.

From a practical standpoint, it may not be desirable to limit youth's driving. Much of young drivers' risk results from simple inexperience. Driving is the only way to gain experience and thus reduce risk. Either youth can gain this experience at the beginning of their driving career or they can gain it later in life. As Ward and others point out, most drivers have a near miss early in their career (Ward et at., 2005) and this type of risky situation is a prerequisite to learning to drive better and reduce risky behaviour. Therefore, discouraging youth from driving because they might have an inexperience-related accident is a poor strategy for reducing overall accident rates.

On the other hand, there is an argument to be made that young drivers' combination of inexperience and a subpopulation of young drivers' propensity for risk-taking makes it desirable to discourage youth driving. It may be that society agrees that young drivers simply should not be on the road; their risk to other drivers may outweigh their own right to mobility by vehicle. However, if this is the consensus, then vehicle insurance fees are a poor mechanism for implementing this policy. Essentially, high insurance fees do not stop youth from driving; they stop low-income youth from driving. If young drivers are really so risky, then it would be more fair to restrict youth driving though a legislative measure rather than a pricing mechanism. For example, a higher legal driving age or an extension of the graduated licensing program would be both fair and effective means of reducing youth's crashes.

Table 7 Comparison of young driver and demographically neutral pricing systems

Impacts					
Pricing Systems	Revenue Neutral & Actuarially Accurate	Fairness	Equity	Emissions Reduction	Collision Reduction
Young Driver Pricing	Yes	Overcharges a large group of cautious drivers Young drivers pay for their aggregate risk	Medium	Slightly higher than flat rate pricing	Medium - High
No Demographic Pricing	Yes	Undercharges risk-taking young drivers All drivers subsidize young drivers' aggregate risk	High	Slightly lower than flat rate pricing	Medium

It would also be possible to charge young drivers a high per-km rate in a distance based program. This solution would result in a large cross-subsidy, as risk-taking behaviour is concentrated among a subpopulation of young drivers. There is, of course, already a subsidy of high risk drivers by low risk drivers. However, charging youth drivers a different rate would increase the concentration of this subsidy, as the cost would fall upon a smaller group of young drivers instead of across the entire insured population (see Table 5). This would substantially increase the overcharging of cautious and skilled young drivers. Despite this drawback, this solution would, by eliminating the sunk cost, open up auto ownership to more youth. At the same time, the high marginal cost would encourage current young drivers to reduce their mileage. It would therefore increase equity of mobility among this population.

3.6.5.3.2 Temporal and spatial pricing

If young drivers are included in a distance based program, they could be charged by time of day or by road type. This variable pricing could either be identical to that for the general population or could be tailored to young drivers' incident patterns. Young drivers' unique crash patterns might suggest that young drivers be subject to a different pricing system. Essentially young drivers have only moderately elevated crash risks during the day, but have very high evening crash risks. In contrast, evening driving is not especially risky for the middle-aged population. Inversely, major arterials are generally risky for the general population, because of their high traffic density. In contrast, alcohol-related crashes, which are highly overrepresented among youth, occur mainly on secondary roads. Therefore, a pricing system designed for the middle-aged population might not reflect youth's risks. On the other hand, a variable pricing system may be a poor method for addressing young drivers' crash risk. As with temporal pricing in general, charging a higher rate for night driving targets only a proxy for risky behaviour. A program that directly addressing drinking and risky driving might be more effective in reducing the high risk associated with nighttime driving. It would also avoid increasing insurance costs for the many young drivers who drive safely at night.

3.6.5.3.3 Summary

Because older drivers are often perceived as posing a threat to other road users, it has been suggested that they be excluded from distance based pricing. However, a close examination of older drivers' collision patterns belies this assumption. First, because of fragility, older drivers tend to be injured more seriously in collisions. However, they are not risk takers and do not disproportionately injury other road users. In terms of absolute numbers, seniors contribute little to total crash risk and this trend is expected to continue far into the future.

In addition to these general characteristics, older drivers can be crudely divided into two categories. The first, because of poor health, has high per-km collisions rates but very low annual mileages. Although this group looms large in the public mind, they absolute contribution to collisions is very small. The second group of seniors has both collision rates and annual mileages comparable to those of the middle-aged population. Grouping seniors into their own annual or distance based pricing systems would have negative implications for this second, larger group of seniors. They would pay a high per-km rate, reflecting the risk of infirm older drivers. This would combine with their high annual mileages to produce much higher annual fees. This high charge for many seniors is unfair and would likely meet public resistance. Because infirm older drivers are few and their mileage is likely quite inelastic this unfairness would not be offset by other benefits, such as large collision reductions.

The inclusion of young drivers in a distance based insurance program has also been controversial in British Columbia. Because young drivers, as a group, have high per-km, annual and absolute collision rates, they are significant contributors to total collisions. The high sunk cost of annual insurance has previously, intentionally or unintentionally, acted as a deterrent to young drivers' licensure. While this has likely had little effect on young drivers' per-km collision rates, it has reduced total collisions by limiting the number of young drivers on the road. Offering distance based insurance to youth would likely result in an increase in the total number of young drivers. This will have the negative impact of increasing collisions. Some of young drivers' crash risk results from simple inexperience, which must be gained at some point in one's driving careers. However, the portion that results from an age-based propensity to take risks may make driving an activity which should not be undertaken by certain youth.

Regardless of the causes of young drivers' risk, annual insurance is a poor mechanism for limiting youth's automobility. Rather, it must be decided whether youth's right to drive outweighs their aggregate risk. If this is the case, then youth's driving should be restricted through legislation, by disallowing them to drive or by forbidding them to drive at high risk times. If this is not the case, then young drivers should be offered distance based insurance. It is possible to either provide this insurance at a per-km rate that covers young drivers' aggregate risk or to offer all drivers the same price, regardless of age. In the former case, young drivers who are cautious and who avoid high risk conditions will be overcharged relative to their risk. In the latter case, all drivers will subsidize young drivers' risk and thus will be moderately overcharged. Either case will create unfairness, but both options would be more fair and offer more equity of mobility among youth than the current annual insurance system.

3.7 Conclusion

Distance based vehicle insurance has the potential to meet important transportation planning goals, particularly reducing vehicle emissions and relieving congestion. Despite this, the fee's design has implications for other public goals. Although there are several good proposals for pricing distance based insurance, a flat per-km rate best balances a number of public goals. These goals include improving the environment by reducing GHG emissions and improving health by reducing ground-level air pollution and vehicle accidents. Another major consideration is improving insurance pricing by increasing equity, particularly across age and income groups. Also relevant is increasing insurance pricing fairness and accuracy by ensuring that premiums reflect accident risk, on both an aggregate and an individual level. A final important aim is protecting privacy and gaining public support for a new insurance pricing system.

Any insurance pricing scheme necessitates trade-offs among these various aims. However, a flat per-km fee is superior to various forms of variable per-km pricing and to the current annual system. A summary of the benefits and drawbacks of the proposed and recommended options is listed below.

3.7.1 Evaluation of options

3.7.1.1 Differential pricing

Differential pricing encompasses a number of pricing schemes that attempt to improve distance based insurances' accuracy by accounting for low mileage bias. This could include charging initial kilometers at a higher rate or charging a higher per-kilometer rate for low mileage drivers. These schemes might improve the system's precision and increase fairness by charging low mileage drivers for their actual risk. However, this improvement would be very small in magnitude, as the overall effect of low mileage bias is very mall. If infirm senior citizens are excluded, the effect of low mileage bias is almost negligible. Moreover, if geographic rating factors are included in per-km insurance pricing, this would likely completely account for this small effect.

The small increase in fairness and accuracy achieved by low mileage bias would be overwhelmed by a resulting decrease in benefits. Differential pricing, by increasing the sunk costs of driving, works against distance based insurance's essential principle – incentivizing reducing vehicle mileage. By charging higher mileages at a higher rate, differential pricing would decrease distance based insurance's potential emissions and collisions reduction. Another concern is that, low-income drivers are disproportionately low mileage drivers. Because of this, a differential pricing system would also reduce distance based insurance's ability to increase equity by reducing insurance costs for low-income drivers.

3.7.1.2 Temporal/spatial pricing

Temporal/spatial Pricing refers to a multitude of systems which price mileage according to time of day, road type or both, reflecting the risk of driving under different conditions. These systems purport to increase accuracy and fairness by closer aligning motorists' risk with their insurance costs. What these systems actually do, however, is increase the pricing system's precision. While this may increase the accuracy aggregate groups of drivers' premiums, at the individual level, it shifts the burden of inaccurate pricing from a large number of drivers to a few individuals. Currently, all motorists pay a small subsidy to a group of motorists who drive in higher-risk conditions and who exhibit risky behaviour. Because risky behaviour is difficult to identify, certain driving conditions, such as rural roads at night, serve as proxies for reckless driving. Under a temporal/spatial system, drivers who drive under these conditions without exhibiting risky behaviour, will alone subsidize reckless drivers. With a smaller group of drivers paying for risky driving, a small number of drivers who are drive cautiously under 'risky' conditions will pay a large subsidy to reckless drivers. It is true that both flat-rate systems and temporal/spatial pricing systems will result in unfair subsidies. However, the great burden placed on a few individuals will likely make more precise pricing systems, such as temporal/spatial pricing, more publicly objectionable.

Temporal/spatial pricing systems are sometimes perceived as being superior to flat-rate pricing in reduce collisions and emissions. While this is possibly true, the magnitude of this advantage has been overestimated. The first reason for this is that the estimated the estimated risk of certain 'high risk' temporal/spatial categories is largely due to a temporal/spatial concentration of certain driving behaviours rather than indicating that certain driving conditions are objectively more dangerous. For example, night driving on rural roads is dangerous, to a degree, because of lack of light, which affect all drivers. However, a large part of the risk comes from the disproportionate amount of drunk-driving and speeding which occurs under these conditions. A pricing system can reduce the number of drivers on the roads under these conditions, thereby reducing the potential for collision with a drunk or speeding driver. However, as many of these types of crashes are single-vehicle crashes, this is of limited usefulness in reducing collisions. Overall, as temporal/spatial pricing cannot directly target the underlying causes of certain driving conditions' high risk, it has limited potential to reduce these collisions.

The second constraint on temporal/spatial pricing's effectiveness is that when insurance pricing is used as a TDM mechanism, emissions and collision reduction come into some degree of conflict. While high collision conditions and high emissions conditions overlap, they are not identical. This means that only emissions or collision can be most intensely targeted through pricing. Any type of distanced based pricing will reduce both emissions and collisions through decreasing total mileage. However, because insurance revenue is zero-sum, targeting either emissions or collisions through higher pricing must come at the expense of the other. In practice, because insurance pricing must reflect collision risk, the likely result will be a decrease in collisions at the expense of a decrease in emissions.

Even if a pricing system could be designed to optimally target emissions and collisions, it would likely be less effective than anticipated. Because humans have a limited ability and motivation to process information, many of them may respond poorly to a complex pricing system. It is common for people faced with complex pricing systems to pay attention to only part of the pricing system or to make incorrect estimates of the cost of different options. Both of these reactions lead to sup-optimal decisions. Another common reaction to the introduction of a complex pricing system is to stick with the status quo, making no change from one's previous behaviour. All of these behaviours would backfire against the pricing system, resulting in either no behavioral change or changes which do not result in the full benefits which would be expected to result from the price differentials.

One compromise which would realize some benefits without these drawbacks would be a simplified temporal system, such as day/night pricing. However, this type of system still does not avoid temporal/spatial pricing's major drawback: privacy invasion (or the perception thereof). Any temporal/spatial pricing system would require some type of in-vehicle transponder. Although transponders do not necessarily have to report vehicle location to ICBC, transponders raise privacy concerns which, for many people, cannot be assuaged by the devices' particular design. This could make a universal switch to distance based pricing an immense political challenge in British Columbia.

3.7.1.3 Demographic pricing

Demographic pricing is an attempt to account for senior's and youth's elevated collision risks. Because these groups have different risk factors, impacts on other road users and internal stratifications, pricing for each group should be treated separately.

3.7.1.3.1 Older drivers

Older drivers, as a group, have elevated collision risks compared to middle-aged drivers. However, this aggregation hides a significant stratification within the group. Older drivers roughly consist of two groups of seniors. The first group is one of infirm older drivers, who have a very high per-km risk but very low annual mileage. The second group consists of healthy older drivers who have both per-km collision rates and annual mileages comparable to those of middle-aged drivers. It is very difficult to design a per-km system that could charge the first group for their elevated risk without grossly overcharging the second group. Furthermore, the first group contributes and will continue to contribute very little to absolute collisions. It also imposes negative excess risk on other road users. Therefore, older driving pricing could only offer a slight gain in absolute collision reduction which would not justify the unfairness of charging higher rates to healthy, high-mileage seniors.

3.7.1.3.2 Young drivers

Because young drivers, as a group, contribute significantly to absolute collisions, their elevated per-km risk is of more concern than that of older drivers. Although some of this elevated risk is due to inexperience, much of it also results from risk-taking behaviour, such as drunk-driving and speeding. As with older drivers, it is difficult to identify risky young drivers before a collision occurs. Because of this, the current insurance pricing system limits the effect of young drives' risk by discouraging youth from driving through the high sunk cost of insurance. It also charges young drivers for some of their aggregate excess risk through charging higher rates for drivers with fewer years of driving experience.

Young drivers' high contribution to total collisions may justify pricing their insurance differently than that of other drivers. There are several options for pricing youth's insurance under a distance based system. First, it is possible to exclude young drivers from distance based insurance, forcing them to purchase insurance annually. This would continue to limit collisions by keeping insurance unaffordable for many youth. A more equitable solution would be to offer distance based insurance at a rate that fully covered young drivers' collision costs. Like annual insurance, this would unfairly overcharge cautious youth for insurance, but it would increase equity by making vehicle ownership affordable for more lower-income youth. A drawback is that this solution would likely increase total collisions by increasing the total number of young drivers. A final option is to raise the driving age. If British Columbians truly believe that young drivers are so risky that their driving must be restricted, then this is a more transparent and equitable system that the current method of keeping lower-income youth off the road through high annual insurance rates.

The first solution of excluding young drivers from a distance based program is not only inequitable, but it forgoes an opportunity to reduce a high risk group's mileage. The latter two options are both superior to this, because they both increase equity of mobility and can decrease individual drivers' mileage. The preferred option, however, must be decided through an open public discussion about youth drivers' risk and their right to automobility.

3.8 Recommended option: flat rate pricing

Flat rate pricing is the recommended option for distance based insurance pricing. Under a flat rate pricing system, all drivers would be charged an individual per-km fee which reflects their current insurance rating factors, such as residential location and vehicle type. With the possible of exception of young drivers, it would not involve demographic pricing. Under this system, all kilometers would be charged at the same rate, regardless of location or time of day.

A flat rate pricing system offers many of the more precise pricing systems' benefits without their drawbacks. It also offers additional benefits not realized by the other systems. In terms of emissions and collision reduction, flat rate pricing would be within the same order of magnitude as more precise systems. While these reductions are likely somewhat smaller than under temporal/spatial or differential systems, the additional benefits of these more precise systems have likely been overestimated by their advocates.

Flat rate pricing also offers a comparable, if not greater, improvement in fairness compared to more precise systems. Flat rate pricing spreads the burden of inaccurate pricing over a large group of drivers who are each under or overcharged for their insurance, relative to their risk, to a small degree. More precise systems shift this burden onto fewer drivers, increasing the cases of extreme under and over charging. Although both systems are unfair, flat rate pricing likely provides the less objectionable circumstance, avoiding situations where insurance costs become unfairly burdensome to individuals.

Finally, flat rate pricing has the greatest potential for increasing socio-economic equity. Flat rate pricing benefits low-income motorists, who tend to be low mileage drivers, by minimizing sunk costs and by not charging higher rates for low or initial mileages. Flat rate pricing also avoids imposing costs on individuals at more vulnerable points in the life cycle – seniors and youth. One possible modification is demographic pricing aimed at youth could ensure fairness and minimize collisions by pricing youth's driving at a cost which covers their collisions and which encourages rationing mileage. The trade-off this would entail between youth's mobility and overall road safety should be opened to public debate in the context of discussing a shift to distance based insurance pricing.

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