10. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

10.1 SUMMARY OF FINDINGS

As part of this research effort, we developed a new methodology for projecting elderly traffic crash fatalities. This methodology separates exposure to crashes from crash risk per se, and further divides exposure into two components, the number of miles driven and the likelihood of being a driver. This component structure permits conceptually different determinants of traffic fatalities to be projected separately and has thorough motivation in behavioral theory. It also permits finer targeting of particular aspects of projections that need improvement and closer linking of projections to possible policy instruments for influencing them.

10.1.1 Aggregate Fatality Projections

Tables 10.1 and 10.2 summarize ORNL's projections of the two fatality measures used in this study, older driver fatalities and the pro-rated total fatalities. Table 10.1 includes fatalities of older *drivers* only. It is important to recall that our measurement of "total fatalities" (Table 10.2), which extends to passengers in an elder driver's vehicle and to drivers and passengers of other vehicles as well as non-occupants in such a crash, divides the total number of fatalities among the number of vehicles involved in the crash. This procedure effectively excludes some deaths from these crashes from the final measure of total fatalities assigned to elder drivers. The concept was adopted as a concession to the absence of information on which driver in a crash was at fault. Others' definitions of "total" fatalities sometimes include the deaths that we have excluded by our pro-rating procedure.

Table 10.1. Older Driver Fatality Projections by Age Group, Male and Female

Age Group	1995	2000	2005	2010	2015	2020	2025
65-69	881	983	1115	1425	1911	2287	2688
70-74	956	1045	1040	1158	1447	1888	2216
75-79	876	1136	1212	1235	1398	1793	2419
80-84	704	1064	1325	1448	1511	1770	2329
85+	474	670	838	1039	1202	1294	1489
Total	**3891**	**4898**	**5530**	**6305**	**7469**	**9032**	**11141**

Table 10.2. Total Fatality Projections by Age Group, Male and Female

	1995	2000	2005	2010	2015	2020	2025
65-69	1121	1267	1464	1917	2628	3221	3871
70-74	1094	1221	1219	1369	1744	2333	2802
75-79	935	1240	1342	1400	1627	2139	2953
80-84	665	1022	1282	1429	1518	1803	2410
85+	377	530	666	840	990	1082	1265
Total	**4192**	**5279**	**5973**	**6955**	**8508**	**10579**	**13301**

10.1.2 Comparison of ORNL Aggregate Fatality Projections to Other Studies

Comparison of our projections with two other recent sets of projections for elderly traffic fatalities in the United States (Burkhardt et al. 1998; Wiggers 1999) is instructive. The three studies differ in their methodologies and consequently in their projections. To facilitate the comparison we begin with a recapitulation of the ORNL projection methodology.

The ORNL Projection

The structure of the ORNL projections is a base of exposure to crash risk, multiplied by a measure of the risk per unit of exposure, multiplied in turn by the population expected to drive. VMT by elderly drivers by gender and age group is the exposure base chosen as representing the most proximate measure of the exposure to the risk of a fatal vehicle crash. The projection of VMT was based on a behavioral regression of the demand for VMT in the previous quarter century (1977-1990/1995), with adjustments made to time trend coefficients used in the projections. The projection of the fatal crash risk per hundred million miles driven similarly relied on a regression model embodying driver behavior. The proportion of the various age/gender groups driving also was expected to be important in the future. Analogously to the projection models for VMT and crash risk, these proportions of drivers were modeled as behavioral decisions with regressions on the previous quarter century of data. These expected proportions of drivers were multiplied by the non-institutional populations in each age/gender group (U.S. Census Bureau projections) to derive the total number of drivers who would drive the miles projected by the VMT projection.

Prominent among the advantages of this projection methodology are its flexibility and its indirectness. Its flexibility derives from separately projecting the major components of future elderly driver fatalities: the exposure, the risk, and the proportion of the population expected to be exposed. Its indirectness lies in the fact that the projections of each of these components of driver fatalities depends on the evolution of variables that are known to affect each component, but the projected magnitude of each component itself is not directly manipulated. The difficulty with an indirect procedure is that the estimates of the behavioral relationships between the directly projected variables such as income, health status, employment status, seat belt use, etc., and the magnitude of the associated components of the fatality projections may turn out to be inaccurate. On a more positive note, however, the projected variables generally are phenomena that would be involved directly in policy efforts to manage elderly traffic fatalities.

Table 10.1 reports ORNL's driver fatality projections for men and women combined.

The Burkhardt et al. Projection

Burkhardt et al. (1998, Figure 2-8, p. 47) project single, total (i.e., male and female) elder driver fatality figures for 2020 and 2030. They do not describe their methodology in detail, but their projections appear to have been based on a linear regression of male VMT on time and possibly other unreported variables over 1968 (or 1983)-1995, with female VMT projected as a constant 1995 fraction of male VMT. Fatality rates per mile were assumed to remain constant at 1995 rates and were multiplied by projected VMT, then multiplied by population projections (presumably U.S. Census Bureau projections). This projection method yielded projections of 18,934 and 23,121 elder driver fatalities in 2020 and 2025, compared with 9,032 and 11,140 projected by ORNL for those years. For 2020 the Burkhardt projection is 210% of the ORNL projection, and that study's 2030 projection is 208% of ORNL's 2025 projection.

Table 10.3. Burkhardt et al. and ORNL Projections of Elderly Driver Fatalities as a Percent of 1995 Traffic Fatalities

	2020	2025	2030
Burkhardt et al.	487%	—	594%
ORNL	232%	286%	—

The Burkhardt et al. methodology tends to elevate fatality projections by several routes. First, the projection of VMT, which they reasonably use as the base of exposure to the risk of a crash, appears to be a straight-line extrapolation of VMT growth over a period during which American travel increased substantially. VMT cannot continue to grow indefinitely for several reasons. First, traveling takes time, more traveling can be expected to take more time, and eventually the projected travel will reach a point beyond which people would no longer be willing to devote their time. Second, highway congestion would reach unacceptable levels which could no longer be alleviated by new construction. The regression from which the VMT is extrapolated apparently does not contain variables that would tend to dampen the growth in VMT as these forces begin to prevail.

The second route by which the Burkhardt et al. methodology gives elevated projections is the assumption of a fixed fatality rate per mile of VMT. Of the three possibilities for the progress of this rate—increasing, constant, or decreasing—their choice eliminates the potential for improvements in safety technology or behavior to depress the trend of fatal crashes in the future. Our own empirical examination of the fatal driver crash rate per mile (per hundred million miles, more precisely) showed negative relationships between the crash rate and two important variables that are widely expected to increase over time, elderly income and seat belt use.

Pegging female VMT to 1995 male VMT dampened the growth of female elderly VMT over the ensuing thirty-five years, which in turn would have dampened the projection of female driver fatalities. Evidently this source of under-projection did not compensate for the two sources of over-projection—the straight-line extrapolation of VMT growth and the constant crash rate per mile.

The Wiggers Projection

Wiggers (1999, Table 2) separately projected elder driver and passenger fatalities by the same age groups used here, and by gender, for 2020 and 2030. Wiggers's methodology assumed that VMT and all other driving behavior would remain constant (1999, p. 4), and he projected driver fatalities as a linear extrapolation of elderly fatality rates per 100,000 population, times population growth. To obtain the trend of elderly fatality rates, Wiggers regressed fatality rates calculated from FARS data on time over the period 1975-1997. To avoid the possibility of projecting negative fatalities for some time in the future, he rejected regressions that yielded negative regression coefficients (1999, p. 4, n. 5). Another motivation for this exclusion of negative coefficients was to represent a diminishing effect of safety improvements on fatalities, but a negative regression coefficient on time would not necessarily imply a non-diminishing effect of safety improvements. (The use of time and the square of time as separate regressors could have accounted for diminishing effectiveness of safety improvements while still permitting them to contribute to reductions of fatalities. A negative coefficient on the time variable and a positive coefficient on time squared would be interpreted as a positive effect of safety technology with diminishing effects over time.)

Wiggers' projections do not show a simple pattern relative to the ORNL projections. We summarize the out-year projections for Wiggers and ORNL in Table 10.4, which compares the ORNL driver fatality projections for 2025 with Wiggers' two years, as percents of actual historical driver fatalities. As the first row of Table 10.4 shows, ORNL's projections are considerably higher than Wiggers' for 2020 for each male age group except 85+ but are slightly lower than Wiggers' for 70-74 and 75-79 females. Although ORNL's 2025 projection and Wiggers' 2030 projection are not directly comparable, the implied growth trends nonetheless can be compared. Wiggers' 2030 projections for the three younger male age groups are substantially lower than ORNL's 2025 projections for those groups and considerably higher for the two oldest male age groups. Wiggers' 2030 projection for 65-69 females is nearly half again the magnitude of ORNL's 2025 projection for that group, his projections for 70-74 and 75-79 women are considerably higher than ORNL's, and the Wiggers 2030 projections for the two oldest groups of women are virtually the same as ORNL's 2025 projections for those age groups.

Table 10.4. Wiggers' and ORNL's Projections of Elderly Driver Fatalities as a Percent of Historical Fatalities

Males					
Projection	65-69	70-74	75-79	80-84	85+
2020 Wiggers*	149 %	145 %	151 %	198 %	319 %
2020 ORNL**	230 %	195 %	208 %	225 %	213 %
2025 ORNL**	267 %	225 %	275 %	295 %	240 %
2030 Wiggers*	157 %	179 %	228 %	360 %	514 %
Females					
Projection	65-69	70-74	75-79	80-84	85+
2020 Wiggers*	241 %	223 %	215 %	220 %	320 %
2020 ORNL**	327 %	202 %	200 %	306 %	408 %
2025 ORNL**	394 %	243 %	277 %	405 %	481 %
2030 Wiggers*	299 %	320 %	361 %	414 %	491 %

* Numbers are given as a percentage of 1993-97 average fatalities
** Numbers are given as a percentage of 1995 average fatalities

The base of exposure to crash risk in Wiggers' methodology is the elderly population rather than any measure of their behavior. As Wiggers himself notes, this choice of exposure base forces an assumption of several dimensions of unchanged driving behavior—not only VMT but the choice of whether to be a driver or not. Neither of these assumptions is reasonable when considering American elderly driving during the first quarter of the twenty-first century.

The consequences of Wiggers' systematic exclusion of a declining fatality rate for his projections are not entirely clear-cut. Assuming that the fatality rate per mile did not decline clearly would have biased the projections upward, but Wiggers buried any changes in VMT within the growing elderly population, which he assumed to not change its driving behavior. Consequently he projected a fatality rate per population that is a combination of safer driving and more driving, and he forced it to yield a net effect reflecting more driving. This empirical result of VMT dominating the fatality projections runs counter to what ORNL learned about the net effect of growing real income on fatalities. Income growth was a major determinant of projected VMT growth and of the driver percentage, and both of those components had a major influence on projected fatalities. However, income was negatively related to the fatal driver crash rate, and its influence on the projected number of driver fatalities through that route outweighed its combined effects through VMT growth and "driver" growth: overall, income growth among the elderly population had a slight, dampening effect on the projection of elder driver fatalities.

Summary

The inability to determine an endogenous asymptote on VMT growth required an exogenous supplementation in the ORNL projection: adjusting the time trend on 65-69 male VMT in 2025 to be no greater than 35-39 male VMT in 1995, but letting all other age-gender groups' VMT grow in empirically determined proportion to VMT in that age-gender group. This is a feature of the ORNL projection worth trying to improve, but it probably leaves our projection of VMT at the high end of what is reasonable and consequently makes our elder driver fatality projections at the high end of what are reasonable. Another possible source of upward bias in the ORNL driver fatality projections resides in the projections of female crash rates. Our regression-based projections show a declining driver crash rate, based largely on income growth and more extensive seat belt use. However, many of the elderly women in the statistical sample on which these relationships are based began driving at later ages whereas the women in, say, the 70-75 age group in 2020 and 2025 well may have nearly 60 years of driving experience. This longer driving experience for the elderly women of the future may further reduce their fatal crash rates. We reiterate that we consider the ORNL projections of elder driver fatal crashes to be at the high end of what are reasonable projections.

The Burkhardt et al. projections are substantially higher than the ORNL projections, for reasons that are clearly traceable in their methodology: upward bias in VMT growth (the exposure base) and a constant fatal crash rate per mile (risk per unit of exposure). Wiggers' projections, using population as the exposure base, do not offer as clear insights into the sources of their differences from the ORNL projections, but that choice of exposure base probably is responsible for the relatively unsystematic differences between his and ORNL's projections, depending on age-gender group. However, it would not be appropriate to declare Wiggers' age-gender specific driver fatality projections superior to ORNL's when they are lower because of the behavioral rigidities built into his projections by his methodology.

10.1.3 Disaggregated Projection Results

Table 10.4 shows ORNL fatality projections as percents of 1995 driver fatalities. Men and women in aggregate, and by age groups, have widely different fatality projections for 2025. The male driver fatalities overall grow by less than the female fatalities, but male driver fatalities for ages 75-79 are projected to grow by more than females in that age group. The female driver fatalities in the 85+ age group are projected to grow by more than twice the male fatalities. The results of that particular age group are attributable to much greater growth in the female driver population and VMT when compared to the male driver population, and a slightly smaller reduction in women's crash risk than men's, which outweighed the effects of substantially larger effect of population growth among males.

Table 10.5. Elder Driver Fatality Projections for 2025 (as Percentages of 1995 Driver Fatalities)

Age Group	Male	Female
65-69	301.3%	457.8%
70-74	236.7%	295.0%
75-79	325.5%	297.0%
80-84	329.3%	441.5%
85+	261.1%	526.1%
Total	290.8%	375.9%

The forces behind the growth of driver fatalities among men and women also differ. In general, population growth had the greatest effect on growth in male driver fatality projections, and growth of driver populations and VMT were the largest influences on the growth of female driver fatalities. Reductions in crash risk were more influential in retarding the growth of female driver fatalities in the 70-74 and 75-79 age groups, and the greatest impact on males ages 80-84. Growth of driver population contributed very little to the growth in male driver fatalities, although it was larger in the 80-84 and 85+ age groups than in the younger groups. Correspondingly, growth of driver population contributed more to growth of female driver fatalities in the two oldest age groups than in the three younger groups. Reductions in crash risk were more important in dampening female fatality growth among the 70-74 and 75-79 age groups than among any other female age group and more than among the corresponding male age groups.

10.2 CONCLUSIONS

The increases in the numbers of elderly fatal traffic crashes will likely be large, but much of the growth will simply be a consequence of population growth. Much of the remaining increase will be a consequence of social changes, particularly the growing similarity in male and female social roles. The outlook would be worse, however, were it not for projections of substantial decreases in crash risks.

Laying the responsibility for this growth in traffic fatalities at the door of population growth and greater mobility does little to offer constructive public policy to address the problem. However, examination of the forces contributing to the growth of VMT per driver, driver percentages, and crash risks offers some insights into constructing policies. First, through its influence on VMT and driver populations, employment status has a relatively important influence on driver fatality projections. A one percent larger fraction of 65-69 year-old men in the labor force would entail a ½% increase in the number of driver fatalities in that group in 2025. This is a comparison of alternative labor force participation rates in 2025 for this age group of men, not a comparison of their labor force participation rates in 1995 and 2025. For 65-69 year-old women, the same change in labor force participation would be associated with a **b**% increase in driver fatalities. We consider this a serious sensitivity to the labor force participation rate. Social Security retirement ages have risen by as much as two years for people born in 1960 or later, which definitely will increase the labor force participation rate in this youngest five-year age group of elderly. Many of these people will want to continue working, and keeping them from the labor force would be counterproductive not only from the perspective of the financial viability of the Social Security program but in terms of their own satisfaction with life. Nonetheless, alternatives such as remote working, working from home, and related developments made viable by the current and future revolutions in communications technologies could be exploited to target this group for effective mobility with lower exposure to traffic crashes.

Second, improvements in health status, as captured by our construct in this study, are projected to lead to an increase in elder driver fatalities. Had we been able to find a satisfactory relationship of health status in our crash risk models, this effect might have been attenuated, but as far as we were able to ascertain, the most reliable consequences of improved health status were to encourage greater mobility—larger driver percentages and more VMT. However, much medical research is being directed to specific ailments that retard such driving-related capabilities as vision fields and depression. Our findings underscore the importance of such research.[1]

A third major influence on driver fatalities, of comparable magnitude to those of employment and health status, was seat belt use. Higher rates of seat belt use can be encouraged, and education among today's younger age groups can build durable habits.

A fourth finding of particular interest is the relative unimportance of income growth in the growth of elder driver fatalities. Since income growth is an important influence on both VMT growth and the growth of driver populations, it would not have been surprising had income growth been a major determinant of elderly fatalities. However, income growth is projected to make even greater contributions to the reduction in crash rates. This retarding effect of income on crash rates has a net lowering effect on total fatalities, although its effects on VMT and driver populations contribute to the growth of elder driver fatalities. Increases in elderly income *do* suggest, on the positive side, that older drivers in the future will be better equipped financially to purchase new vehicles with newer safety technology and correspondingly that education programs about the availability and effectiveness of such equipment targeted to them could be funds well spent.

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[1] For only one example of this type of targeted research, see Rubin et al., 1998, especially Section 13, "Preliminary Study of the Relationship between Vision and Crash Involvement."

10.3 DIRECTIONS FOR FUTURE RESEARCH

10.3.1 The Role of Infrastructure and Equipment

Our approach to projection of elderly traffic fatalities permits us to attribute those changes over the next twenty-five years to specific causes, such as better health putting more elderly drivers on the roads. With the data available, however, we have been unable to identify the effects of specific technological and infrastructure changes over the past quarter century and are hence unable to incorporate projections of how they could be expected to affect elderly fatalities in the future. The best we have been able to do so far is to identify time trends in VMT and the percentage of drivers which are not otherwise explained by the variables in the model. To project effects of, say, ITS innovations or further vehicle safety improvements on elderly fatalities we could vary the time trends in the VMT and driver components of our projection (time trends were not successful in the fatality rate regressions), but the magnitude of the effects would be hypothetical. More direct study of the effects of equipment and infrastructure changes on the components of elderly fatalities could permit more precise projections of the direct and indirect consequences of improvements in those elements of the transportation system. Study of these improvements, coupled with investigations of negative effects such as deteriorations of certain infrastructure components and the increasing negative impact of driver distractions such as cellular phones, can offer more informative guidance for policy choices. See also Section 3.3.5 on current research on these technologies.

10.3.2 Asymptotic Projection of VMT

The regression model underlying the projection of VMT does not contain any internal mechanism that would tend to limit the growth of VMT as its various determinants increase in value, a phenomenon we should expect because driving requires people to use their time. Although we have imposed an asymptote on the projections of VMT, we still consider our fatalities projections to be at the high end of what is reasonable, since we think that the base projections of VMT may be high. Our attempts to estimate a household production model of VMT were hampered by lack of data. This production model could help account for the fact that higher income would give people a higher cost of using their time to drive as well as directly increasing their demand for driving. It may be possible to combine data on time use from other surveys with NPTS data to better account for the dampening effect of time requirements on increasing VMT. Other, complementary approaches to estimating a household production model could examine interactions of vehicle fuel efficiency, fuel, and vehicle safety features simultaneously with the demand for VMT.

10.3.3 Additional and Improved Measures of Health Status

A third area that needs further research is the construction of a measure of health status. In the present effort we developed a method to transfer structural relationships regarding the ALS construct from the NHIS survey on health to the NPTS survey data base on driving behavior. It would be useful to identify other health indicators relevant to driving behavior for such cross-data base transfer. Even more useful would be to combine questions about driving and health status directly in a single survey, but that would lead to research capabilities only well in the future. Other more comprehensive data bases that link health status with VMT, driving vs non-driving, or crash information—or any combination of the three travel behaviors—should be examined for the possibilities of behavioral modeling to further identify choice relationships. The relative frailty of older cohorts, meaning the likelihood that a crash that a younger driver would survive could kill an older driver, is lost within the age-specific crash risks estimated in our crash risk regressions and projected from those equations. Identifying the contribution of such frailty to elderly fatalities or crash risks would be empirically demanding. Such identification would require individual-level observations on crashes with information on type of crash (head-on, side, single-vehicle, multiple-vehicle), estimated speed of impact, make/model/year of vehicles of each party to the crash, and age of driver (or of each passenger killed). These information requirements might be met from some state records if not at the national level. As a policy issue such frailty may be reduced by improving elderly health trends or through general technological improvements in safety equipment that can help a frail person survive a crash.

10.3.4 Comparison of Younger and Older Drivers' Behavior

This study's finding of the importance of employment status as a determining force in elder driver fatalities points to the question of how much of this effect is a pure age effect and how much is comparable to the exposure to crash risk faced by all working drivers. This issue can be addressed to some extent with currently available information, but projection of younger fatalities into the future would require income projections for the younger age groups, which may behave quite differently from those of the elderly living between 2000 and 2025. Another issue that bears further investigation is age-specific seat belt use. The seat belt use information available for this study was population-wide. If age- and/or gender-specific seat belt use information were made available, it might be possible to study seat belt use as a choice made simultaneously with other driving choices such as VMT, driving, and crash rate.

10.3.5 Alternative Transportation Options for the Elderly

As noted in Section 10.3.1, there are several uncertainties regarding mobility of the elderly in the future. The impacts of smart cars, infrastructure enhancements, and innovative safety programs and/or components can simply not be quantified at this time. However, current trends are to solve the problems of traffic congestion, air pollution, and safety through better engineering and creative approaches to public transportation rather than by building new roads. The need for alternative mobility options for the elderly is well recognized, and various concepts for making transit use more acceptable to elderly riders are being explored.

Additional research is needed in the areas of public transportation as well as other alternative mobility options. For example, more information on public transit is needed (1) to identify the features that the elderly desire in a transit system (price/method of payment, ease of entry/exit, safety, security, etc.), (2) to determine where and when and for what purposes the elderly would use transit, (3) to describe potential options for rural conditions, and (4) to develop a methodology for predicting transit success. In addition, public comment would be helpful to quantify the appeal and/or value of elderly communities that encourage pedestrian trails or "golf-cart" types of transportation within the community. Other approaches to achieving mobility and an acceptable quality of life for the elderly should also be explored. Although many of these research components have been considered in part (as noted in Section 3), there has been no attempt to consolidate all of the research into a single data repository.