The Interdependency of Increasing Life Expectancy and Driving Life Expectancy of Elderly Populations

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Abstract

In this paper, we explore the effect of increasing longevity on driving life expectancy, especially in the elderly population. The concern is that when life expectancy is much longer than driving life expectancy, seniors have to rely on alternative means of transportation in their remaining years. As life expectancy increases, it affects not only their health and financial status, but also their mobility, which can be measured by driving life expectancy. The degree of the elderly population's mobility is an important factor in their quality of life. Since life expectancy and driving life expectancy have very different patterns for different gender and age groups, we calculate these two variables accordingly. Then we compare driving life expectancy to life expectancy to estimate the number of surviving years without driving, which is defined as *mobility dependency*. This article's conclusions are intended to help develop public policies that affect the mobility of seniors.

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I. Introduction

An aging population has caught the attention of the social, financial, health care and retirement systems, which directly and/or indirectly affect the quality of life of the elderly. A sophisticated retirement system can secure the elderly's financial independence, while the ability and willingness to drive is essential to assure their mobility independence. This article intends to link improved mortality with the mobility of the aging population. Rappaport and Parikh (2002) address the issues of increasing longevity at very high ages. They discuss the impacts of longevity on retirement financing, on the insurance and housing businesses, on spouses and family members and on society. However, the impacts of longevity on mobility have been missed in the extant literature. In this study, we quantify these impacts by introducing *cessation rate* and *driving life expectancy*, which are parallel concepts to mortality rate and life expectancy.

Mobility independence can be used as a measure of the quality of life of the elderly. The study conducted by Evans (1998) points out that non-drivers at 75 years old and older are among those most at risk of social isolation due to inadequate transportation service following reduced mobility. Therefore, it is of interest to investigate the trend of driving life expectancy in comparison to life expectancy and to investigate the time period during which the elderly need to depend on alternative transportation. Advocating elderly mobility independence is likely to create a society dilemma since there may be negative aspects such as increased accident rates. A National Highway Traffic Safety Administration research note (1995) shows that the licensure rate[1] was higher in 1990 than in 1983 at all ages, as was average annual mileage. In addition, the large increase in licensure rate is attributed to the increase in the number of drivers who are 65 year old and over, which suggests an increase in elderly mobility independence. The reported average annual mileage increases much less for older drivers. The research note also shows that older drivers have approximately three times higher the accident risk per mile driven.

Stamatiadis and Deacon (1995) conducted a study of accident trends with increase in age. In terms of the effect of age, they conclude that middle-aged drivers are safer than younger drivers, who, in turn, are safer than older drivers. For cohort effects, the article suggests that more recent cohorts of older drivers are safer than more distant cohorts, and more distant cohorts of younger drivers are safer than more recent cohorts. On the other hand, when gender effects are taken into account, female drivers are safer on average than male drivers, younger female drivers are safer than younger male

[1] Licensure rate at a given age is the ratio of number of issued drivers' licenses to total population in the corresponding age group.

drivers, but older male drivers are safer than older female drivers. Furthermore, a Massie, Campbell and Williams (1995) study of traffic accident involvement by driver age and gender showed that the corresponding relation of the number of accidents per mile driven to an age group presents a "U" shape. Whereas males tend to be involved in more fatal accidents than females are, females have higher injury rates than males do. Licensure rate is higher for males than females, and the difference between genders increases as age increases. At the same time, men drive more than women do, while the difference is smaller in the younger and older age groups. Based on the findings in literature, we analyze how mobility dependency in different age groups and genders reflects different driving patterns.

The study of cessation rate can be referred to Foley, Heimovitz, Guralnik and Brock (2002). They used data from the Asset and Health Dynamics Among the Oldest Old (AHEAD) study conducted in 1993 and from a follow-up survey in 1995 to conclude that males from age 70 to 85 and above 85 have a longer driving life expectancy than females in the same age cohort, whereas women have a longer life expectancy. In contrast with Foley's study, we use data from 1994 to 2003 for the general population as well as for the driving population. With continuous data and the widened population base instead of survey data, we expect to obtain more accurate results and a possible trend in mobility dependency for seniors.

II. Methodology

1. Mortality Rate and Cessation Rate

By definition, the mortality rate at age x over an n-year period, ${}_nq_x$, and its relation with the general population at age x, l_x can be written as Equation (1).

$$l_{x+n} = l_x \cdot (1 - {}_nq_x) \tag{1}$$

Likewise, the driving population for age x after n years can be expressed by Equation (2).

$$(l_{x+n})_d = (l_x)_d \cdot (1 - {}_nc_x) \tag{2}$$

There, $(l_x)_d$ is the driving population at age x, and ${}_nc_x$ is the cessation rate measuring the proportion of the driving population at age x stopping driving over the n year period.[2,3]

2. Expanding Life Table

To highlight mobility dependency for the elders, we expand the life table from age 85 and above to age 95 and above and based on 5-year age group for analysis. We assume that the exponential rate of mortality increase at old age presents a linearly decreasing trend, as Coale and Guo (1989) did for the 5-year age group.[4] In our case, we assume the mortality increase declines linearly from age group 75 to 79. Let k_x be the Gompertz parameter and m_x be the central death rate.[5]

$$k_x = \ln\left(\frac{m_x}{m_{x-5}}\right)$$
$$k_x = k_{75} + s*(x-75)/5$$
$$\Rightarrow s = \left(\ln m_{95+} - 5*\ln m_{75} + 4*\ln m_{70}\right)/10$$

[2] Foley et al. (2002) define driving cessation as people who are still alive in the follow-up survey, but who have stopped driving.

[3] The consideration of double decrements is important in the cessation rate since both mortality and not being able to drive cause driving cessation. However, people who are not able to drive may be able to drive later due to, for example, improvement of their health status. It is possible to measure cessation rate by excluding mortality rate with an assumption that mortality rate is the same for driving and non-driving population. This assumption may not be reasonable for the older age population since health is the reason most of them give up driving. We are indebted to Robert Johansen for this comment.

[4] Research by Buettner (2002) provides a good discussion about projecting mortality rate to construct a life table.

[5] The mortality rate for the age group of 95 and above is chosen from the least difference between estimated and exact population for age 85 and above.

So,

$$m_x = m_{x-5} * \exp[k_{75} + s \cdot (x - 75) / 5]$$

Since we assume uniform distribution of death, the relationship between mortality rate and central death rate is

$$q_x = \frac{m_x}{1 + 0.5 \times m_x},$$

3. Total Life Expectancy and Driving Life Expectancy

Assuming life expectancy follows a uniform distribution, the total number of surviving years of population at age x for n years, ${}_nL_x$, is defined as the following:

$${}_nL_x = l_x \cdot (1 - {}_nq_x) \cdot n + l_x \cdot {}_nq_x \cdot n / 2$$

Then, total life expectancy $\mathring{e}_x$ is defined as the following:

$$\mathring{e}_x = \int_{t=0}^{\infty} {}_tL_x dt / l_x \tag{3}$$

Similar to the concept of life expectancy, the driving life expectancy, $(\mathring{e}_x)_d$, can be expressed as the following:

$$(\mathring{e}_x)_d = \int_{t=0}^{\infty} ({}_tL_x)_d \, dt / (l_x)_d, \tag{4}$$

where $({}_nL_x)_d = (l_x)_d \cdot (1 - {}_nc_x) \cdot n + (l_x)_d \cdot {}_nc_x \cdot n / 2$, and $(l_x)_d$ is the driving population at age x.

The expected number of years that the elderly need to rely on transportation other than driving is defined as mobility dependency, which is the difference between the life expectancy and driving life expectancy. That is,

$$\mathring{e}_x - (\mathring{e}_x)_d = \int_{t=0}^{\infty} {}_tL_x dt / l_x - \int_{t=0}^{\infty} ({}_tL_x)_d \, dt / (l_x)_d.$$

III. Data

General and driving populations are needed to derive mortality rate from Equation (1), cessation rate from Equation (2), life expectancy from Equation (3) and driving life expectancy from Equation (4). We use the number of licensed drivers as an estimator for the driving population with data from the Federal Highway Administration (FHWA).[6] The general population is from the Census Bureau. Data from 1994 to 2003 are used in this study. Due to data limitations, the driving and general populations are grouped in five-year age increments, starting from age group 45 to 49, going to age group 85 and above. Therefore, n is equal to 5 for all equations. For example, the age group 45 to 49 at 1994 with $n = 5$ is the age group 50 to 54 at 1999. Consequently, the derivations of cessation rate, mortality rate, life expectancy and driving life expectancy are based on five-year age groups.

IV. Results

Our data show that both the elderly general population (over age 65) and the elderly driving population are increasing over time. While the number of elderly male drivers increases at about the same rate as the elderly male population, the number of elderly female drivers increases faster than the elderly female population. In other words, in recent years, the ratio of driving population to general population, $R(x)$, for elderly males is nearly constant in a given age group, but the one for elderly females is increasing.[7] This result shows that, *at the same age group*, elderly women have better mobility and independence now than in the past, which suggests that they rely less on their family members or alternative transportation. However, the ratio $R(x)$ declines as age increases. For men, the ratio is less than 90 percent in the 75 to 79 age group and above. For women, the ratio is lower and decreases faster than the one for men as age increases. In addition, the percentage of elderly drivers to total drivers increased from 1994 to 2002, as Table 1 shows. The older the age groups are, the more the percentage increases, and the percentage for female increases more than that for male. For example, in 2002, the percentage of elderly drivers age 65 and beyond is about 15 percent of the

[6] The number of licensed drivers is not a perfect measure of driving population because some people may still have licenses but have stopped driving and use licenses for identification, while other people may drive without a license. However, this is the most appropriate estimation available for this study.

[7] One possible explanation for this situation is that, in the earlier years, it was less common for women to drive. As society changes, more women drive, and more women learn how to drive at older ages. It is also possible that women used to depend on their husbands to drive. Since the life expectancy is longer for women, they have to drive themselves after their husbands' deaths or drive as caregivers when their husbands are not able to drive anymore. In the second case, a non-driver can become a driver later, which should be handled with care when double decrements in mortality and mobility are considered. We would like to thank R. Johansen for pointing out this possibility.

total drivers. From 1994 to 2002, the percentage of the elderly drivers age 75 and beyond to the total drivers significantly increased by 24 percent.

TABLE 1
Percentage of Elderly Drivers to Total Drivers
For elderly drivers 65+, 70+ and 75+ from 1994 to 2002

	65+			70+			75+		
YEAR	Male	Female	Total	Male	Female	Total	Male	Female	Total
1994	13.86%	14.42%	14.13%	9.06%	9.50%	9.27%	5.04%	5.26%	5.15%
1995	13.89%	14.49%	14.19%	9.13%	9.64%	9.38%	5.11%	5.41%	5.26%
1996	13.89%	14.58%	14.23%	9.21%	9.83%	9.51%	5.23%	5.62%	5.42%
1997	13.93%	14.73%	14.33%	9.34%	10.07%	9.70%	5.36%	5.85%	5.61%
1998	13.79%	14.60%	14.19%	9.31%	10.06%	9.68%	5.41%	5.93%	5.67%
1999	13.87%	14.77%	14.32%	9.45%	10.29%	9.87%	5.57%	6.20%	5.88%
2000	13.84%	14.83%	14.33%	9.48%	10.40%	9.94%	5.67%	6.37%	6.02%
2001	13.96%	14.87%	14.42%	9.58%	10.43%	10.00%	5.77%	6.43%	6.10%
2002	14.16%	15.09%	14.62%	9.79%	10.67%	10.23%	6.05%	6.76%	6.40%
Increase % (2002/1994)*	2.19%	4.64%	3.47%	8.16%	12.34%	10.33%	19.97%	28.36%	24.28%

* Increase % is the percentage change of the ratios of elderly drivers to total drivers in 1994 and 2002, i.e., $R(x)_{2002} / R(x)_{1994} - 1$.

Furthermore, we analyze life expectancy and driving life expectancy to identify the number of surviving years that the elderly will depend on alternative transportation. Table 2 shows life expectancy for all age groups in five-year intervals, and driving life expectancy is presented in Table 3.[8] We define mobility dependency—the number of years depending on alternative transportation—as the difference between life expectancy and driving life expectancy for individuals of a given age in a given chronological period. Figure 1 shows the average mobility dependency for men and women in each age group. For most of the age groups under the 70 to 74 group, males' mobility dependency is less than two years. It means that most of males drive until they die. As expected, when compared to men, women have longer life expectancies as well as longer driving life expectancies. However, women have longer years of mobility dependency; in other words, women have more years depending on alternative transportation than men do.

[8] Foley et al. (2002) assumed that morality for 85 and over for 5 years (${}_5q_{85+}$) is one. We followed their assumption, which can be seen in Table 2, that life expectancy for 85 and over has a sudden drop. We have the same assumption for the cessation rate. But we don't see that sudden drop, because this is a reasonable assumption since the expected driving years over 90 is close to zero. However, we are working on extending the life table to get more accurate life expectancy for advanced ages.

TABLE 2
Life Expectancy in the Period from 1999 to 2003

$\overset{\circ}{e}_x$ in Equation (3) with n = 5

	Men					Women				
	1999	2000	2001	2002	2003	1999	2000	2001	2002	2003
45-49	22.42	22.07	21.43	21.95	22.07	26.65	26.01	25.16	25.76	25.72
50-54	22.31	22.05	21.98	20.80	20.63	27.16	26.61	26.40	25.01	24.61
55-59	21.26	21.29	21.05	20.72	20.06	26.43	26.28	25.86	25.49	24.53
60-64	18.14	18.42	18.67	18.76	18.60	22.91	23.12	23.34	23.59	23.30
65-69	14.06	14.30	14.50	14.81	15.20	17.59	17.88	18.10	18.70	19.16
70-74	11.18	11.33	11.63	11.89	11.98	14.16	14.25	14.49	14.98	15.11
75-59	9.51	9.60	9.60	9.63	9.62	12.01	12.09	12.03	12.20	12.20
80-84	9.08	9.10	9.11	9.20	9.18	10.62	10.65	10.64	10.92	10.96
85-89	5.25	5.26	5.27	5.33	5.32	6.52	6.54	6.54	6.72	6.76
90-94	3.98	3.99	3.99	4.05	4.05	4.70	4.72	4.71	4.85	4.88
95+	2.78	2.79	2.79	2.83	2.83	2.99	3.00	2.99	3.07	3.09

TABLE 3
Driving Life Expectancy in Years from 1999 to 2003

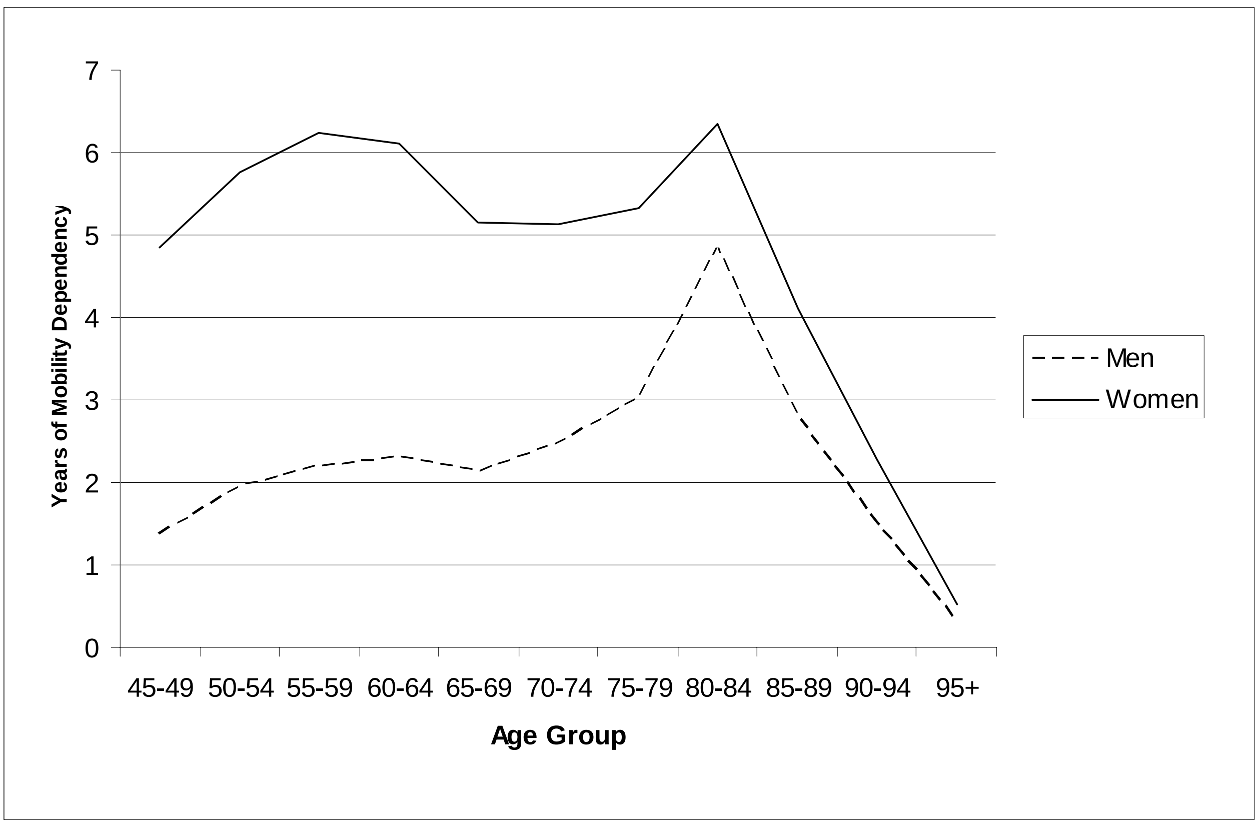
$(\overset{\circ}{e}_x)_d$ in Equation (4) with n = 5

	Men					Women				
	1999	2000	2001	2002	2003	1999	2000	2001	2002	2003
45-49	20.84	20.48	20.31	20.75	20.73	21.24	20.84	20.71	21.09	21.16
50-54	20.38	20.20	19.63	19.11	18.65	20.99	20.79	20.23	19.70	19.22
55-59	19.24	19.15	18.81	18.44	17.73	20.07	19.99	19.62	19.16	18.50
60-64	16.01	16.25	16.29	16.43	16.10	16.92	17.19	17.22	17.31	17.01
65-69	11.98	12.20	12.39	12.78	12.90	12.56	12.88	13.10	13.48	13.68
70-74	8.80	8.96	9.08	9.37	9.43	9.10	9.29	9.42	9.67	9.82
75-79	6.44	6.53	6.50	6.70	6.71	6.65	6.75	6.71	6.89	6.91
80-84	4.16	4.26	4.25	4.37	4.36	4.32	4.40	4.35	4.50	4.47

TABLE 4
Mobility Dependency Years in the Period from 1999 to 2003

	Men					Women				
	1999	2000	2001	2002	2003	1999	2000	2001	2002	2003
45-49	1.59	1.59	1.11	1.21	1.34	5.41	5.17	4.45	4.67	4.57
50-54	1.93	1.85	2.35	1.69	1.98	6.17	5.82	6.17	5.31	5.38
55-59	2.02	2.14	2.24	2.28	2.33	6.36	6.29	6.23	6.33	6.03
60-64	2.13	2.17	2.39	2.34	2.50	5.98	5.93	6.12	6.28	6.29
65-69	2.08	2.09	2.12	2.03	2.30	5.03	5.00	5.00	5.22	5.48
70-74	2.38	2.37	2.54	2.52	2.55	5.06	4.96	5.07	5.31	5.30
75-79	3.07	3.07	3.10	2.93	2.91	5.35	5.34	5.32	5.31	5.28
80-84	4.92	4.84	4.86	4.83	4.82	6.30	6.25	6.29	6.42	6.49
85-89	2.75	2.76	2.77	2.83	2.82	4.02	4.04	4.04	4.22	4.26
90-94	1.48	1.49	1.49	1.55	1.55	2.20	2.22	2.21	2.35	2.38
95+	0.28	0.29	0.29	0.33	0.33	0.49	0.50	0.49	0.57	0.59

Figure 1. Average Year of Mobility Dependency



V. Conclusions

In recent years, policy makers have increased their focus on the impacts of an aging population on the social security system, including retirement and health care financing, especially as the baby boom generation is approaching the defined aging group. In this study, we advocate that when aging issues are discussed, mobility independence needs to be taken into account. This study contributes to providing a measure for mobility dependency in corresponding age groups. It will not cause a major problem when mobility dependency for an advanced age group is around one year, since life at advanced ages often ends after a substantial institution stay. However, when mobility dependency is more than four years, especially for elderly women, more public policies are needed to enhance mobility independency and maintain their quality of life. One possible way, which also takes road safety into account, is to increase driving life expectancy; the other is to reduce the need to drive or find alternatives to driving.

Similar to life expectancy, health is one major factor affecting driving life expectancy. Three groups of health conditions have their influences on driving to different degrees. First, health conditions such as vision relate to requirements for the renewal of driver's licenses. Poor vision, eye diseases or blindness can cause the termination of driving. Second, some health conditions affect driving but are not tested in renewal process, including dementia and lack of acuity. Third, serious health problems such as stroke or heart attack force the elderly to stop driving. This group of health issues also has a direct effect on life expectancy. People with serious health problems cannot drive but still have driver's licenses until renewal.

To balance mobility for seniors and road safety for the general public, some states have adopted more stringent rules for the elderly to renew licenses, such as a road test or frequent renewal process, to revoke the licenses of those drivers with the second group of health conditions. However, Rock (1998) shows that a more frequent renewal process for older drivers does not appear to produce any benefit. Hopkins, Kilik, Day, Rows and Tseng (2004) suggest policy changes to reflect the increasing number of older drivers with dementia by requiring physicians who treat patients with dementia to report to authorities, which would revoke the licenses of the drivers with dementia. At the same time, the more stringent license renewal standards can contribute to higher cessation rates in the older age cohort, thereby increasing mobility dependency. Generally speaking, improving the health of the elderly is the way to increase driving life expectancy and decrease mobility dependency.

With regard to reducing the degree of dependency or finding alternatives, there are several options for the elderly. One is moving to areas with convenient public transportation or within walking distance to most places. This entails senior emigration to urban areas and this emigration pattern should be more obvious for areas with higher degree of urban sprawl. Second is that the government should improve public transportation beyond urban areas. Third is the use of taxis, which would impose more financial stress on the elderly. Finally, have caretakers drive for elderly. The caregiving ratio is used as an indicator for this purpose.[9] As expected, the caregiving ratio increases as baby boomers approach the caregiving age. This is good for the pre-baby boomer generation, but not for the baby boomers themselves. Unfortunately, when the baby boomers need alternative transportation, it is more likely that caregiving will not be an option. Then, more public transportation will be needed. However, the lower cessation ratio for both genders and the higher ratio of drivers to general population for women in recent years may reduce the severity of the alternative transportation problem if these trends continue. At the same time, when baby boomers approach retirement, the number of people in need is going to increase dramatically. Those options are not mutually exclusive but supplemental to each other. The effects of alternative options are left for future research.

[9] Rappaport and Parikh (2002) quoted that The Robert Wood Johnson Foundation (1996) used the caregiving ratio to measure the availability of unpaid caregiving, which is mostly from adult children. The ratio is the population between age 50 to 64 to the population of 85 and above. The age group 50 to 64 is chosen because those ages are the closest to the average age of caregivers.

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