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The Aging Society from the Perspective of Urban Infrastructure and Community Environment: Searching for Policy and Technological Innovation

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Abstract This study reviews how an aging society can be connected to the urban-built environment, transportation system, infrastructure, and climate change topics from the perspective of policy and innovation in science and technology. Each topic was described with the aging society that we will encounter in the near future. Based on the expected discussions, we suggested how policy and technological innovations may interact with the new emerging society. Especially, digital transformation is expected to hyper-connect the aging society beyond physical barriers where numerous policies and innovations in science and technology shed light on the elderly population. We observe, however, that this cannot be achieved only by the government sector; rather, municipal governments and local communities, as well as private sectors, all together need to prepare for the new society of the aging population. Furthermore, an ideal approach is to accommodate multidisciplinary studies that can address the policy and technological innovations simultaneously and collectively. By doing so, we can minimize the negative impacts when an aging society approaches.

Keywords Aging society, built environment, community impacts, inter-collaboration between public and private sectors

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I. Introduction

The global population doubled between 1960 and 1999, increasing from three billion to six billion people. In addition to the population growth, another recent demographic phenomenon of the growing senior population may bring significant consequences to our society (Hunter, 2000). An aging society is also one of the most dominant demographic trends in U.S. history. In 2050, the population aged 65 and over is projected to be 83.7 million, almost doubling its estimated population of 43.1 million in 2012 (Mather et al., 2015). As a result, the senior population is expected to increase from 13 to 20 percent of the entire population of the U.S. by 2030 (Pendall, et. al., 2012). It was expected that this population shift would cause significant impacts on the U.S. public finance and labor market.

A large volume of research has addressed a severe implication in public employee pension and health care financing due to the increase of disbursements (Kisser et al., 2012; Pew Charitable Trusts, 2013). Municipal governments such as the cities of Detroit and Stockton already filed a bankruptcy protection petition due to underfunded pensions and the costs of retiree health care, and many municipal governments are facing similar financial challenges. According to a recent report, 61 major municipal governments in the U.S. had a shortfall of $99 billion in the fiscal year of 2009 for their pension obligations (Pew Charitable Trusts, 2013). Further, an aging society may make new shifts in the nations' labor workforce. As the baby boomers are expected to leave the workforce, it is projected that about 83 million new workers would enter the U.S. workforce between 2010 and 2030 (Myers et al., 2013). Among them, 58.6 million (71%) would replace a large number of older workers who expect to retire. The expected lack of skilled labor force stemming from the retirement rush of baby boomers in years.

While the impact of the aging population on public finance and macroeconomic matters is widely discussed, relatively little is known about its impacts on infrastructure and the built environment in the community. An aging society predominately led by baby boomers moving into the elderly age is a demographic phenomenon that societies never experienced before, not only in terms of its magnitude but also in terms of the characteristics. Baby boomers' lifestyle will be quite different from one of their parents' generation. They will be working in retirement, taking bridge jobs, living longer in good health, living in couples in the suburbs, continuing to drive cars, and having financial equity in houses or financial flexibility (Brown et al., 2010; Pitt-Catsouphes et al., 2012). Due to their unique lifestyle, their demands on public services in everyday life will differ from those of a generation ago. The physical urban space and the type of the community that baby boomers prefer may not be the

one found from conventional retirement communities. However, the question, how well municipal governments and local communities estimate and prepare for the demands, is rarely discussed and remains unanswered.

The purpose of this paper is to raise awareness of how the aging population is related to the urban-built environment, transportation system, infrastructure and climate change, and connect the community design needed for the aging population in the aspect of technologies and innovation aspects. This paper sheds light on the readiness of municipal governments and local communities when accommodating the unique demands of this massive population cohort. Analyzing the elderly's demands on individual features associated with various urban issues aforementioned, this paper attempts to elaborate the interconnected relationship between the demands and urban infrastructure in communities and to extend the discussion searching for policy and technological innovations. Emphasizing the collaboration between public and private sectors, this paper also suggests both long- and short-term policy strategies and technological innovations that can support the elderly and help municipal governments and communities be prepared. After describing each subject experienced, the paper intends to raise discussion points and set a broad direction in a quest to be needed for addressing the significant shifts of urban infrastructure demands for an aging society rather than proposing solid, comprehensive resolutions and strategies.

II. Aging and Housing Choice

Environmental psychologists have argued there are transactions between individuals and their physical environment. The built environment of a community in which individuals reside influences their behaviors and experiences. In an aging society, it is natural to hypothesize that the elderly population is more forcefully associated with the physical conditions the elderly involved than other age-cohorts because the aging group has spent a longer time in the community. Type of communities and the physical settings in everyday life, therefore, are strongly correlated with the essential activities of the aging population.

The elderly population requires the need for a variety of specialized housing and supportive services. This brought up the issues of housing options for the elderly. Still, the elderly living in our communities is increasing, but it does not accurately suit the traditional notion of assisted living or retirement community. This is because many elderly people live longer in good health, drive cars not necessarily transit-dependent, live in couples, and have financial equity in houses or financially comfortable. Additionally, a new, significant phenomenon regarding their housing choice is a lifestyle choice known as "Aging in Place"

(Myers, 2013). Unlike their parents' generation, the elderly and retirees do not want to move into a smaller home, assisted living, or a retirement community. Instead, they want to be remaining in their own home for the later years of their life. Seventy percent of the 65-plus population in the metropolitan area stay in the suburbs. According to a community survey of the National Association of Realtors, people over age 60 said that they preferred a suburb to an urban location by almost a three-to-one margin. Therefore, making an age-friendly community becomes an important, significant challenge in an aging society. New strategies for "age-less" master-planned communities and complete communities attempt to accommodate the elderly's housing demands, creating age-friendly communities. Although the approaches are slightly different each other, the primary focus of them is to create a healthier, friendlier, more convenient, and more sustainable neighborhood providing housing for all population, such as apartments for young adults, single-family houses for families, and condos for seniors (Rosenthal, 2009).

The new trends in the choice of housing and community raise health issues of aging population due to the strong correlation between residents and the conditions of the physical environment around their residence. Built environment characteristics of local neighborhoods are directly related to health outcomes such as cardiovascular disease (CVD), depression and injury, which in turn influence physical functioning, independence, quality of life and overall health. Of many significant health factors of the elderly, walking is an important one that closely relates with the built environment. The elderly group is often retired, spending more time in their home and community. Walking in the neighborhood is the most common type of physical activity in which individuals are engaged. A study of older adults in Atlanta found that those living in a more walkable neighborhood were 32 percent less likely to be overweight (Kerr et al., 2012). Therefore, designing safe, walkable communities can play a substantial role in influencing physical activity for older adults (Kim, 2019). Several studies have found that neighborhood features such as the availability of sidewalks, pleasant scenery and topography, nearby destinations for accomplishing daily activities, and the presence of neighborhood footpaths are all firmly correlated with increased rates of walking and physical activity (Kim et al., 2018; Dumbaugh, 2008; Hugh, 2009). The built environment also influences the elderly's mental health. Social networks are critical to mental and emotional well-being. For the elderly, the local social networks in their own neighborhood are particularly critical. Research is unequivocal in relating people's perception of their neighborhood to both objective indicators of its social quality and health and well-being (Hugh, 2009). Living in a more walkable area was related to fewer depressive symptoms among older men via greater social connectedness (Kerr et al., 2012).

III. Aging and Transportation

The societal impact from the growth of the elderly population segment can be far beyond financial, medical and housing issues. As aging is in a gradually progressive process affecting all living persons, their demands for safe mobility will be different from those of the younger population. As mobility affects one's quality of life and psychological health, the traditional transportation policy focusing on commuting behavior should be re-examined because most of the elderly do not commute.

According to the 2017 National Household Travel Survey (FHA, 2018), older adults traveled shorter distances and shorter travel times per day than younger adults (33 miles vs. 37 miles in the average daily person miles, respectively). The trend of decreased travel with age (less trip-making) is evident. The elderly population prefer automobile travel, compensating for physical limitations by traveling less, instead of shifting modes (Giuliano, 2004). Consequentially, time spent on all out of home activities decreases for the elderly while the share of social and recreational activity time as a proportion of all out of home activity increases. A significant decline in travel takes place after age 75 (Giuliano et al., 2003) when probably the elderly experience declines in their physical, sensory, perceptual or cognitive abilities. For this reason, their trips are concentrated in the middle of the day, avoiding night time or rush-hour travel.

Transportation mobility is a critical element for the quality of life regardless of their age. Especially, older people who have physical and cognitive difficulties in driving face more significant mobility challenges. Walking is the second most reliable mean of mobility for the elderly after losing their physical and/or sensory ability to drive (Bailey et al., 1992). Public transit, paratransit, supplemental transportation programs, and others are currently available for older adults. However, these options are often inadequate for older adults' travel needs. The elderly are also more sensitive to travel convenience and less likely overall to be a transit user, although the elderly residing under dense urban environment in large cities frequently uses public transit. Older people have a difficult time walking to the bus stop, waiting for the bus, climbing aboard, standing in the bus where no seats are available, and knowing when to get off. Paratransit or shared ride services may impose difficulties to older people by not being available or the need to schedule well in advance (Peck, 2010). Instead, many older Americans rely on family and friends for transportation when they enter this stage (Dickerson et al., 2007). Local density plays a critical role on the elderly's travel decision. The older elderly group makes fewer and shorter trips in low-density areas relative to the other age cohorts (Arentze et al., 2008). However, "Aging in place," the elderly's preference for remaining in the homes selected in earlier stages of the life cycle, means aging in the suburbs for the majority of the elderly. Unfortunately, there is a significant structural lag

between the growing elderly population and the built environment in suburban communities due to limited transportation alternatives, low density, and lack of nearby destinations (Kim, 2011).

Traffic safety is another crucial transportation issue in an aging society. Elderly drivers tend to be more involved in different types of crashes compared to other age groups. In 2017, 6,784 elderly people were killed in traffic collisions (NHTSA, 2019). While the fatality rate per 100,000 people of the elderly (0.13) is higher than the rate of younger population (0.11), despite lower rates of drinking and driving and higher rates of seat belt use. As multiple complications expand with general declines in health, cognitive function, and medical conditions, the crash rates are even higher among people over 75 years old. Older drivers are more often involved in intersection crashes than younger drivers, especially when they turn left against oncoming traffic. Older drivers are also more likely to be involved in multiple collisions (Hakamies-Blomqvist, 2004). This is more seriously observed during the snowing season (Hess et al., 2016).

The elderly also have higher rates of pedestrian deaths and injuries than younger people. In 2017, 5,977 and 78,000 elderly pedestrians were killed or injured in traffic collisions, respectively (NHTSA, 2019). While younger pedestrian crashes tend to occur near drinking venues mostly at night and on weekends, older pedestrian crashes often occur close to the home or at other frequently visited locations such as shopping centers during the daytime. Although it is difficult to find out the causal factors of older pedestrian crashes, some explanations are available. Older pedestrians take a longer amount of time to cross a road and stop more frequently than younger pedestrians do. Collision risk is associated with the frailty of older pedestrians due to their declines in their physical, sensory, perceptual or cognitive abilities. Road design may contribute to crash risks for older pedestrians, such as wide roads with multiple lanes, fast walking cycles for pedestrian crossings, illegible road signs, and so on (Dommes et al., 2012).

IV. Aging and Infrastructure

As for age composition, owing to the population boom of recent decades and increased longevity across the globe, the current human population size has both the largest cohort of young people (age 24 and under) and the largest proportion of the elderly in history (Hunter, 2000). This significant demographic shift to aging society induces changes in the global environment accelerated in unprecedented fashion. Understanding population characteristics helps illuminate some of the mechanisms through which population dynamics affect

infrastructure issues. Primarily, it is clear that the aging population will change the demand and consumption pattern of infrastructure such as water and energy.

The most influential determinants for residential water demand are price and household income. The higher the household income, the higher the level of water use, particularly through water-consuming amenities such as gardens, pools, saunas, and dishwashers (Scleich and Hillenbrand, 2009). However, it is obvious that the increase of the elderly population will change the conventional patterns of water demand and consumption. Varis (2009) pointed out the indirect impacts of aging population on water consumption along with urbanization. Aging population causes changes in economic growth, lifestyle, housing, and industry, and consequentially impacts on the pattern of water consumption. Some studies envision that the aging population probably increases water consumption and demand due to the characteristics of an aging society including smaller household size, their behaviors such as frequent toilet flush, and more time spent at home (Varis, 2009; Blokker et al., 2010; Lyman, 1992). On the other hand, numerous studies suggest that the elderly population is a population cohort consuming less amount of water because they are likely to be frugal water consumers compared with younger population who use more water for higher frequency of laundering and for recreational purposes, and tend to live in a smaller apartment/house with few water-using appliances and water-saving attitudes (Nauges and Thomas, 2000; March et al., 2012; Matos et al., 2014). Note again that it is still inadequate to say that sheer increases in the elderly population cause an increasing demand on water resources. However, since the elderly's water consumption is highly correlated with their income, housing choice, and attitudes, it is clear that the population shift by the retirement of baby boomers will change the trends of their water consumption.

Unlike the relationship between an aging society and water consumption, there is a consensus on the impact of the growth of the elderly population on energy consumption. An aging society will contribute to higher energy consumption and demand, especially residential energy demand. Household size is one of the most significant demographic factors on residential energy consumption. While aging may have direct consequences since energy consumption tends to change over the lifespan, aging could also indirectly impact an associated decline in household size, and consequently, a loss of economies of scale in energy use at the household level (O'Neill and Chen, 2002). In the United States from 1993–1994, one-person households used 17% more energy per capita in comparison to two-person households. The trend of aging in place causes higher energy consumption since one- and two-person "elderly" households live in a large house that is more suitable for households with children.

Additionally, there are several factors that cause higher residential energy consumption by elderly persons (on a per capita basis) than by younger persons.

They include space heating, water heating, appliances and air conditioning, growing house occupancy, a plethora of electric-powered sensing devices, acute health-concerning health care equipment, and new medical technologies requiring advanced computer and telecommunication devices (Yamasaki and Tominaga, 1997; Schipper, 1996). Low incomes seem to be a negative contributor to energy consumption; however, its effect is limited (Yamasaki and Tominaga, 1997). Another energy reduction factor by the elderly population is driving. Elderly singles, who own fewer cars and drive considerably less than others, can contribute to energy savings (Schipper, 1996). However, it is crucial to consider that the lifestyles of the elderly are themselves changing. Tomorrow's energetic retirees may carry the mobility patterns experienced in their younger years and continue to drive their private vehicles as much as they can, diminishing the impacts of energy reduction by less driving.

V. Aging and Climate Change

The demographic influence on climate change appears primarily in three forms: contributions to greenhouse gas (GHG) emissions stemming from industrial productions and energy consumptions that use fossil fuel; land-use changes, such as deforestation; and other consumption-related processes such as livestock production (Hunter, 2000; Kim et al., 2015). Based on the influence factors, it is hypothesized there is a relationship between the growth of the elderly population and GHG emissions, consequentially climate change due to the elderly's lifestyle associated with land use, transportation, and water/energy consumption. However, there is no clear consensus on how elderly growth will influence future GHG emissions. Some estimated aging is a more critical demographic factor related to the increase of carbon emissions in the developed world, even though urbanization is more significantly observed in developing countries (Jiang and Hardee, 2011). This is because the elderly group uses more energies for heating and cooling of floor space (O'Neill and Chen 2002). Another group expects the elderly can contribute to the reduction of GHG emissions because the group's energy consumption can be relatively compensated by the reduction of labor productivity and supply (Dalton, et. al., 2007; Dalton, et. al., 2008; York, 2007; Weyant, 2004).

While there is no consensus on how the growth of the elderly population will impact on the pattern of GHG emissions, vulnerable older adults will become victims of weather-related natural disasters and extreme weather events caused by climate change (Gamble et al., 2013). They include extreme heat events (e.g., heat exhaustion, heatstroke, dehydration, acute renal failure, and nephritis), hurricane intensity and precipitation, flood, and increased risk of wildfires after drought (Cannon and DeGraff 2009; Ebi and Meehl 2007; Ostro et al., 2009;

Kodra et al., 2011, Richardson et al., 2014; Park et al., 2017a; Kang et al., 2018; Park et al., 2017b; Park et al., 2017c). These severe weather events may also lead to mental or emotional trauma before, during, and following the event as well as a range of secondary health impacts including the availability and safety of food and water; interruptions in communications, utilities, and health care services (Cherry et al., 2009). Climate change can also affect air quality by increasing the formation of ground-level ozone and by leading to higher atmospheric concentrations of fine particulates, allergens, and dust. Climate change can facilitate the spread or emergence of vector-, water-, and food-borne diseases in areas where they had been limited or had not existed previously (GCRP 2009). These effects, though not restricted to older adults, are typically more severe due to preexisting medical conditions (Laumbach 2010). Although the unfortunate situation of elderly populations becoming victims of climate change seems to be inevitable.

VI. Policy and Technological Innovation for the Aging Society

Although many baby boomers are delaying their retirement, most of them will eventually retire within the next ten years. In 2010, the baby boomers were ages 46 to 64, and the participation rate of the prime age group was 82.2% in 2020. The conventional characteristics of the elderly will be reconfigured as baby boomers move into the elderly age cohorts. Indeed, this population cohort will be entirely different from the previous cohort, living longer in good health with sticking to the traditional behaviors. This paper raises a question if our society is ready to provide services and infrastructure that can accommodate the demands required by the growing, unique aging population cohort, rather than giving answers.

This paper indicates the complicated, interconnected relationship between the lifestyle of baby boomers and their surrounding environment. For example, a clear, new trend of the elderly's housing choice called aging in place is identified. Aging in place is a matter of not only housing (or community) choice but also transportation, health, and energy consumption (consequentially, related to climate change). While positively contributing to the elderly's mental health due to the continuity of their social network, aging in place has negative side-effects such as limited mobility options and high energy consumption since the elderly remain staying in a large suburban house. Since all these matters are connected to each other, it is vital to develop a comprehensive approach incorporating the issue. Increasing efforts to identify built environments and social elements that contribute to developing aging-friendly communities can be an example. In an aging society, attempts to help older adults age in place can also potentially improve the community as a whole. The World Health Organization (WHO)

published a comprehensive report to present indicators of aging-friendly communities. WHO defines an aging-friendly community as a community that adapts its structures and services to be accessible to and inclusive of older people with varying needs and capacities (WHO, 2007). WHO identified eight areas to promote aging-friendly communities: housing, social participation, respect and social inclusion, civic participation and employment, communication and information, community support and health services, outdoor spaces and buildings, and transportation. Adopting the holistic approach is beneficial to convert suburban communities to an aging-friendly community and support the elderly's aging in place.

While creating an aging-friendly community is a long-term goal since it takes time to do so, creative public-private partnerships can be a short-term strategy. In this sense, this study moves to collaborative policy strategy and technical innovation supported by multiple agencies, organizations, and companies that can support the elderly's demands. Regarding the elderly's limited mobility, municipal governments can provide senior-oriented paratransit services and volunteer driver programs, but these alternatives are not as effective as fixed-route transit (e.g., bus). Still, it is hard to provide fixed-route transit in the suburban residential areas (Kim, et al., 2016). An emerging technology such as rideshare service (e.g., Uber and Lyft) can provide the elderly with an additional convenient mobility option. This short-term resolution substituting private car and/or paratransit service can be extended to the discussion with autonomous vehicle (AV) development goals. Advanced automobile technologies can help older adults to drive longer by enhancing safe driving. They include GPS route guidance, infrared vision enhancement systems, distraction management systems, lane-departure warning systems, and collision-avoidance systems. AV can be an ultimate resolution for the elderly's mobility regardless of their physical, sensory confidence to drive. With the collaboration with AV companies, municipal governments potentially operate a rideshare service with a fleet of AV in suburban and urban environments.

In the same vein, the issue of the elderly's high energy consumption in their suburban house can be resolved by the collaborated efforts of policy strategy and technological innovation. Many governments already adopted subsidy, incentive, and rebate programs for residential solar-panel systems. The purpose of the programs is to promote home energy production via the eco-friendly, renewable energy source. When the programs combine with the advance in technologies improving the photovoltaic power of solar panels, the elderly's high energy consumption can be lessened. Vigorous technology R&D programs can focus on substantially improving the energy efficiency of housing units occupied by the elderly and of every energy-consuming device such as medical types of equipment. By doing so, the approach partially can reduce fossil fuel consumption that contributes to climate change.

Another critical concern in an aging society is the elderly's health. In general, this is considered as a matter of the private sector and the medical industry. Due to the emerging "longevity economy" created by the U.S. baby boomers who drive massive markets as consumers, leaders, learners, and/or workers, health care and medical industries indeed pay more attention to the elderly as a significant consumer group. However, there is a clear role of local governments for the elderly's health. Since walking is important health factors for the elderly, designing communities for older adults' safe walking environment is the responsibility of local governments in an aging society. The design must encourage the elderly's pedestrian activities in the communities and protect them from collisions, considering the declining visual, auditory, and kinesthetic senses to maintain mobility, autonomy, independence, and well-being. For example, impaired hearing and vision need to be compensated by louder signals and increased lighting. Loss of cognitive functioning may inhibit a way of finding and orientation, so clear signage is required. More resting places may also be needed for older adults who have low stamina.

VII. Conclusion

This study reviewed how an aging society could be connected to the urban built environment, transportation system, infrastructure, and climate change. We provided various discussions on how policy and technological innovations may interact with the new emerging society. The new society we encounter will be connected hyper-connectively beyond physical barriers where policy and innovation in science and technology shed more light on the elderly population.

However, this cannot be achieved only by the government sector; rather, municipal governments and local communities, as well as private sectors, all together need to prepare for the aging society. For the purpose, this study raised how various dimensions can be connected to the aging community through the support of policy and technological innovation. Further, more dimensions such as the risk of disease contamination, virtual reality and augmented reality in the aging society should be added, which can be addressed in the following study. Even though this study emphasized comprehensive and collaborative approaches to addressing the new future of aging society, it is clear that an ideal approach is to accommodate multidisciplinary studies that can address policy and technological innovations. This study can minimize the negative impacts when an aging society approaches.

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