Prospective living arrangement of China's urban elderly and development of an Agent-based Simulation (ABS) model for elderly care needs

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Prospective living arrangement of China's urban elderly and development of an Agent-based Simulation (ABS) model for elderly care needs

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Abstract: As China is characterized by a large ageing population, and its rapid speed of ageing, urbanization, and socio-economic transformation, the senior service issue is both typical and urgent. To support the urban planning and decision-making of relevant policies for senior services, which is significantly challenging, this research employs the multi-agent simulation (MAS) approach to simulate the complicated process of Chinese senior service provision. The approach defines the elderly, day-care centers, and residential aged care facilities (RACF) as the kernel agents, determines the behavior rules of different agents, and confirms the interaction between agents, individual agents and urban environments. Altogether nine simulation modules were designed and integrated. This study focuses on the diversifying elderly population, complexity of the senior services system, and the uncertainty of the developing background. Seniors' socio-economic attributes such as income, family structure, education and hukou status, day-care center, and RACF agents' characteristics, such as price, location, service standard, public /private status, were emphasized at a microscopic scale. Using a bottom-up approach, neighborhood differentiation was considered the main determinant of senior service needs. Through the design of different policy-scenarios, critical parameters were determined to have the most important influence on senior service needs and their provision. The regulation of these crucial indicators will be a great scientific support to the planning of provisions for senior service facilities and to the decision-making of environmental improvement policies in different urban neighborhoods. The MAS approach is recognized as a modelling paradigm for capturing the dynamics of complex systems. This research is especially useful for supporting the provision of elderly service facilities and the environmental improvement of livable urban neighborhoods through future urban planning.

1. INTRODUCTION

Due to the global ageing trend, senior service provision is gradually becoming a critical issue worldwide. Senior service is a complicated, dynamic, systematic social problem, significantly subject to population

growth, the provision of socio-economic institutions, economy, regional infrastructure, culture and value, and service management. The senior service system is composed of a large number of autonomous stakeholders (service suppliers, elderly persons, policy makers, etc.) who play fundamental roles within the system, and interact with each other in a dynamic urban environment.

The sixth census in China, conducted in 2010, demonstrated that the population above 60 years old had reached 178 million, accounting for 13.3% of the total population. It was predicted that by 2030, this figure will double (CPC Central Committee and State Council, 2011). Due to its reduced fertility rate and increasing life expectancies over the last few decades, China is experiencing rapid demographic changes. Since ageing overlays with industrialization, urbanization, and socio-economic transformation (Peng, 2011), the elderly service issue in China is relatively more typical and presents more challenges, such as with the difficulty of prematurely ageing before acquiring sufficient retirement funds, or with problems due to the large population of disabled seniors, "empty-nest" seniors, and the traditional role of families decreasing. At present, the most acute and fundamental contradiction in senior service is structural imbalance between the demand and provision.

To resolve this problem, three important factors must be adequately addressed, which are demographic transitions, diversification of seniors, and policy reform. The one-child policy has played a key role in the demographic transition by greatly reducing the number of children available to support ageing parents. A common concern for urban seniors is the hesitation over whether to enter a care facility, which presents a departure from tradition, or to rely on the care of a single child. After the policy of reform, socio-economic differentiation (e.g. income, hukou status) has emerged in China, which has affected senior service demand between elderly people with different characteristics. The utility levels of senior care services vary with socio-economic diversification. Health care reform, social security system reform, and introduction of a household registration system have been undertaken recently, and a series of policies related to senior service will be formulated in the near future. All of the policies will have important implications for the viability of future senior service strategies.

Most of the existing studies on senior service needs are multi-disciplinary, because it is difficult to clarify this problem using the analysis methods of any one discipline. According to the behavioral model in gerontology and sociology, three sets of variables can account for differences in health service use among the elderly, which are predisposing variables (e.g. age, sex, and education), enabling variables (e.g. family income, financial capacity of the elderly and their accessibility to services), and need variables (e.g. symptoms of health and illness, functional health problems, and perceived need for health care) (Andersen, 1995). From sociology and psychology, the health belief model focuses on the role of the individual's perceptions in seeking the health services, not on the role of demographic and social conditions (Hooyman & Kiyak, 1988). It suggests that seniors' beliefs about health problems, perceived benefits of action and barriers to action and self-efficacy are triggers for health service utilization (Janz & Becker, 1984). The P-E fit model, presented by environmental gerontologists, shows how the integration of the elderly with their physical and social environments hugely impacts health service demand (Lawton & Simon, 1968; Longino Jr, Perzynski, & Stoller, 2002; Rowles & Bernard, 2013). Studies on public health show that China has experienced an epidemiologic transition in its leading causes of

death, from infectious disease and acute illness to chronic disease and degenerative illness (Gong et al., 2012). The changes lead to an ageing society with changing health and disease patterns, and different health service expenditures (Levit et al., 2003).

To address the mismatch between the demand and supply of elderly care services, research shows the importance of different factors, such as status and way of life, the relationship between the elderly and their urban living environment, access to facilities(e.g. location, care service), and the effect of policy (Barnes, 2002; Gao, X. L., 2013; Gao, X., Yan, & Ji, 2012; Golant, 1979; Moos & Lemke, 1979; Shapiro & Tate, 1985; Yan & Gao, 2014). Nevertheless, the statistical method, social approach, and traditional spatial analyses are too macroscopic, aggregate, and static to solve this problem. They are unable to respond to an elder individual's behavior and an individual facility's operation in a diversifying society, and to understand the concrete challenges in this comprehensive, systematic, and integrated problem.

A Multi-Agent System (MAS) has an advantage in its ability to simulate complex, dynamic systems (e.g. urban land use and urban transportation changes), by modelling the interacting, autonomous agents in a dynamic environment (Batty, 2011; Ligtenberg et al., 2004; Shen et al., 2011; Suryanarayanan, Theodoropoulos, & Lees, 2013). Agents have behaviors, often described by simple rules, and interact with other agents, which in turn influence their behaviors and the whole system (Macal & North, 2010). In an urban development simulation, the most important things to consider are the selection of agents, definition of behavior rules, expression of interactions between agents, and the extraction and importation of environment variables (Chen, Gao, & Shen, 2012). Not all of the stakeholders should be considered as agents. The confirmation of an agent's behavior is prior knowledge – based on and impacted by the research target, involving an interdisciplinary study, in which all of the theoretical conflicts must be resolved. Circular interactions among the agents are simultaneous and difficult to model. The inter-face of the urban environment contains the social, economic, environmental, cultural and policy related variables which are the essential inputs of the simulation and needs to be quantified.

Therefore, an MAS is used to construct the Elderly Caring Service Supply (ECSS) Model in order to reasonably provision elderly care services dynamically, and to expand the application of MAS to model the urban complex system.

Based on the gerontology, sociology, urban geography, etc., the essential agents are selected (e.g. the elderly, facility), the agent evolution laws and the behavior rules are confirmed, and the agent behavior modules designed. According to the interaction between various agents, the agents' behavior are integrated, framing the affecting mechanism of different agents' modules, simulating the urban elderly care services demand-supply system at the micro scale, and identifying the macro evolution law. Consequently, based on the forecast outcomes of micro behaviors of elder individuals and facilities, the macro laws of the whole demand-supply system of elderly care services can be concluded upon. According to this, intellectual support can be provided more reasonably and predictably in a manner that addresses the planning and provision of elderly care services. Moreover, in the complex environment, the micro-level simulation and scenario analysis will bring a new perspective to regional and urban planning, and significantly influence the distribution and allocation planning of infrastructure and public service facilities.

2. FRAMEWORK AND AGENT-BASED SIMULATION

2.1 General framework of the simulation

The ECSS Model aims at developing, testing, and applying a new type of integrated urban elderly services supply model that simulates the interaction between the elderly and their environment (Figure 1) in a whole system, under the conditions of a rapid ageing and urbanization process.

Firstly, the characteristics of elderly people in the urban region are defined, such as age, health status, income, education, etc. Then, demands for spatial interaction are created, such as shopping, leisure travel, participation in activities, receiving care, etc. There are also elderly who need more care for their declining health and loss of independence. The daily activities, health care, and specific treatments of the elderly occur in different areas with different levels of accessibility and service convenience, which consequently triggers their reactions (e.g. their morale, mood, well-being, life satisfaction). Secondly, the adjustment of living arrangements as a deliberate behavior of seniors significantly influences the senior care services demand. Urban senior service systems will provide services accordingly and improve the life quality of the elderly. In the whole process, there is a remarkable need to consider the different aspects of the environment such as personal space, buildings, neighborhoods, facilities, etc. Their locational and physical attributes should be taken into account in the interaction between the physical environment and the elderly population.

There are two important feedbacks in this system model: 1) Subjective feedback: Based on the existing senior services and urban living environment, elderly people will conduct an evaluation of their wellbeing which will influence their future decisions regarding their living arrangements; 2) Objective feedback: The allocation of elderly care service facilities will impact the modes of urban living arrangements for seniors where the provision of urban senior service systems is significantly restricted by a government policy.

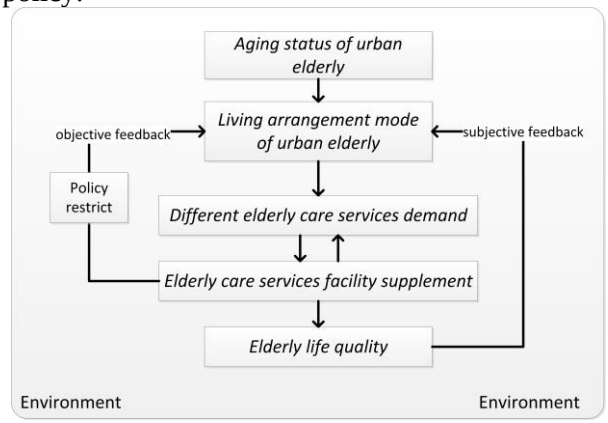

Figure 1. ECSS Model framework

This theoretical framework recognizes elderly diversity, complexity of the senior service system and the uncertainty of the developing characteristics. It can be used for predicting the growth of the elderly population and the demand for senior services in future, and assessing to what extent these urban environments can effectively meet the needs of elderly people for senior services, evaluating the efficiency and impact of potential social policies that support senior service systems.

2.2 Selection of agent and module relationship

According to the multi-agent system, the essential agents are first selected, and then their behavior rules confirmed and the interactions between agents, and between agents and their environments, constructed through various simulation modules.

The ECSS Model is microscopic, and includes three types of agents, 1) elderly agents, 2) residential aged care facility agents, and 3) day care center agents. For elderly agents, which are the kernel agents in this simulation, all health and economic status, social support changes, livelihoods, modes of living arrangements, and elderly care facility selections will be modelled using multi-agent based simulation. For residential aged care facility agents and day care center agents, the profit or non-profit, location, capacity for visitors, content of services, and cycles of business operation (business cycles) can be simulated per individual facility. The interactions between elderly care service demand (e.g. home-based services, community-based services and care services from aged care facilities) and facility supply (e.g. residential aged care facility, day care center, and hospitals) are modelled at the level of individuals. Within the simulation environment, urban policies, such as senior service facility plans, will be input into the simulation environment. In addition, an urban governor/policy framework will be simulated to manage, restrict, and supervise the provision of the elderly service system, and also to select the urban development strategy, and regulate the urban environment construction (e.g. hospital, leisure space, transport facility, etc.). The urban ageing process, urbanization, and the developing macro-level background of this model are also essential factors in the simulation, impacting upon the behavior of different related agents, and should be represented and input as well.

According to the characteristics of different types of agents, the elementary behavior and decision-making processes are encoded as basic computer program codes, each running a different module. The ECSS Model consists of nine modules. There are five modules conducted by elderly agents, which are the life cycle module, care pattern shift module, living arrangement and care pattern choice module, relocation module, and facility choice module, and four modules executed by the day care center, or residential aged care facility (RACF) agents, which are the day care center business cycle module, day care center's location module, RACF business cycle module, and the RACF's location module. The simulation modules of the ECSS Model interact in various ways with each other. Interactions between the modules, and between agents and the environments, are operated by a coordinating program. Existing research models and empirical findings are the foundation of simulation modules which perform the essential mechanisms of the agents' behavior rules and their interrelationships with other agents or environments. Proceeding is therefore an introduction of the related studies and findings.

3. BEHAVIOR RULES OF THE ELDERLY

3.1 Elderly lifecycle module

Ageing is the central topic of study in gerontology. One's life course is determined by their life trajectory, important life events, and role/status transitions (Riley, Johnson, & Foner, 1972). Elder (1975) found that there are

key times and places that encapsulate experiences over a lifetime, which shape the life course of individuals. Life events generally refer to things such as schooling, marriage or divorce, retirement, death of a spouse and so on (Li, Deng, & Xiao, 1999). The role/status changes of the elderly mainly include the biological, social, and psychological aspects, such as the transition of sensory function, cognitive abilities, lifestyles, social contribution, intergenerational relationships, values, and well-being (Hooyman & Kiyak, 1988; Moen, Dempster-McClain, & Williams Jr, 1992; Riley, 1987).

The different dimensions of a life course are defined according to the study by Morgan and Kunkel (2011) and are shown in Table 1. Age related life course events in later life include children leaving home, retirement, death of a spouse, declines in health, and reductions in income, which significantly impact the later life of the individual.

Table 1. Various dimensions of life course

Age	**...-20**	**20-30**	**30-40**	**40-50**	**50-60**	**60-70**	**70-80**	**80-90**	**90-100**
Life course	…	Young adult	Adult	Middle age		Later maturity		Old age	
Job/ retirement	…	Job experiment	Job advancement		Retirement planning	Retirement occurs		Retirement	
household	…	Marriage/parents	parents		spouses			Widowhood?	
Intergenera-tional relationship	…	Kids under 6	Kids 6-12	Kids 12-18	Adult-adult		Empty nest	Dependent on child?	

According to their age, the elderly can be subdivided into pre-elderly (55－64 years old), young-elderly (65－75 years old), middle-elderly (75－85 years old), and old-elderly (85+ years old) (Atchley, 2000; Bures, 1997; Carr & Komp, 2011; Longino Jr, Perzynski, & Stoller, 2002). Carr and Komp (2011) propose a different conception of life course using functional distinctions between ages. According to their concept, the third age of the elderly is described as the period of life that occurs after retirement but prior to the onset of disability, a period in which individuals have the capacity to remain actively engaged in society. The third age is brought to an end by the fourth age, characterized by declining health and loss of independence. The third age emphasizes the role of health status in the life course, and is a response to the concept of productive ageing in gerontology, which focuses on seniors' productive participation (e.g. whether they are engaged in work, taking care of grandchildren, caring for sick friends, or taking part in educational training) (Morgan & Kunkel, 2011).

Although transitions in the life cycle influence the decision-making process of elder individuals, they tend to plan well within their particular limitations (Clausen, 1993; Elder, 1975). Therefore, as rational actors, the living arrangements, health care, social care, and facility selections of later life have already been considered within elderly decision-making scopes, and abide by the principle of maximum utility of the elderly within their current life courses (Wu, C. P. & Jiang, 2006).

3.2 Care pattern shift module

From the life course modules of the elderly, different life courses within the physical, psychological and social ageing process are examined. Living environments, including the physical environment, social environment and senior care services, are closely linked with seniors' lives. So, how does the urban environment impact elderly citizens in different life courses, and

influence their lives? Answering this question is the essential task of this module.

Elderly people are more sensitive to their environment than young people (Hooyman & Kiyak, 1988). Golant (1979) argued that elder people's geographic experience in their neighborhoods involves a complex set of experiential categories, including action, orientation, feeling, and fantasy that together provide a holistic expression of the individual's adjustment (such as a move to an institution, locomotion within the proximate environment, and movement during long-distance vacations) within their physical and psychological capabilities and unique life history. Lawton (1982) developed a predictive model for the behavior of senior citizens, based on the relationship between the senior and their living environment. After Lawton's ecological theory, the relationship between the elderly and the environment has been studied further. Evans (2009) provided research on the social well-being of elderly people living in "housing with care" (for example, retirement villages and extra care housing). A sense of community is critically important for elderly people's quality of life. The influencing factors include social networks, inclusive activities, diversity, and the built environment. Phillips et al. (2005) categorized these dwelling conditions as the interior environment (for example, indoor lighting, crowdedness, temperature, security devices, lifts/escalators, etc.) and the exterior environment (lighting in public spaces, green areas/parks, recreational or sitting and rest areas, passages, flyovers/subways, air pollution in the estate/community, etc.), and demonstrated the greater impact of the interior environment on residential satisfaction than the exterior environment. Yan and Gao (2014) revealed that in different neighborhoods (for example, traditional courtyard housing blocks, low-income rental housing neighborhoods, commercial housing neighborhoods, etc.), residential environments play a significantly different role in the ageing process for the diversity of seniors who are ageing in an RACF in China.

Therefore, based on the fitness of the elderly person, and their well-being or satisfaction, their adjustments or behavior can be predicted (for example, the changing of living arrangements). The elderly care pattern changing-desire module is simply the process to assess the relationship between the elderly and their living environment, and the probability of certain behaviors.

3.3 Living arrangement and care pattern choice module

The relationship between the elderly and their environment influences their mental status (for example, depression), quality of life, and individual behavior. The adjustment of living arrangements and residential locations can be viewed as a manifestation of the ways in which elderly people have adjusted to the social, behavioral, and environmental factors.

Generally, living arrangements include independent living (living alone or with a spouse), co-residence (living with at least one child or other kin), and living in an institution. The particular arrangement has many implications for the current well-being of an elderly person, and is selected dynamically and should be responsive to changes in individual circumstances and to changing expectations about the future (Phillips et al., 2005). Functional losses and lower life quality, for example, due to diseases such as Alzheimer's disease, require an increase in informal or formal care services and more supportive dwelling environments. Therefore, lower life quality functions as a predictor of the higher probability of movement into a skilled nursing facility (Kaplan,

D. B. & Andersen, 2013). In addition, different values, cultural specificity, and the assimilation of elder people are essential factors in the decision-making of living arrangements. Foreign-born, Asian elderly in Canada/America were usually living under the auspices of family reunification, and so the percentage living with family instead of living alone or with a nonrelative is highest, and their socioeconomic status correlates with this pattern (Boyd, 1991; Kamo & Zhou, 1994; Phua, Kaufman, & Park, 2001). Although in China the traditional preference of the elderly has been to live with their children, recently, due to the influence of acculturation, economic feasibility, and demographic availability, there is an increasing preference for elderly people to live independently or to enter an institution (Gao, X., Yan, & Ji, 2012).

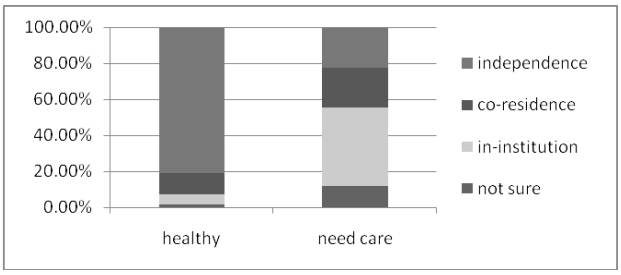

Figure 2. Chinese elderly's living arrangement based on Beijing survery (Gao, X., Yan, & Ji, 2012)

The selection of living arrangement in the elderly population is associated with their functional losses and changes in the level of received care and assistance (Dostie & Léger, 2005). Based on current living arrangements, as an individual's physical energy, mobility, and health status changes, they need more services, including Activities of Daily Living (ADL) care, and Instrumental ADL (IADL) care. These services belong to different care patterns which are supplied by various care providers (See Table 2).

Table 2. Relationships between living arrangement and urban long-term care system

Living arrangement	**Care pattern**	**Care provider**	**Long-term care (ADL care, IADL care)**			
			Emergency/ acute treatment	Technical recovery health care	Recovery health care (non-technical)	Supportive real-time health care
In- institution	Residential care	Hospital	Δ			
		Residential care facility		Δ	Δ	Δ
Co-residence/ independence	Community care	Community-based facility /Day care center				Δ
	In home care	At-Home Care Company		Δ	Δ	Δ
		Community elderly center				Δ
		Relatives/ Friends: Informal care service				Δ

Policy concern over elderly living arrangements arises from the large effect of living arrangement choices on elderly care and welfare, especially for those suffering from physical limitations or health problems. This concern may be especially cogent in rapidly developing countries, such as China, where the percentage of elderly living independently (alone or with their spouse) has increased substantially. However, public senior social services remain relatively defective. For example, most of the elderly who are living in public nursing homes are retired, rather than disabled old-elderly; there is thus a shortage of care facilities. Some studies on this have already been

conducted; for example, Dostie and Léger (2005) suggested that policies may be more effective at reducing institutionalization if, among the elderly living independently, policies are targeted at married females with fewer children and at encouraging seniors to return to community care or in-home care if they are living in a nursing home.

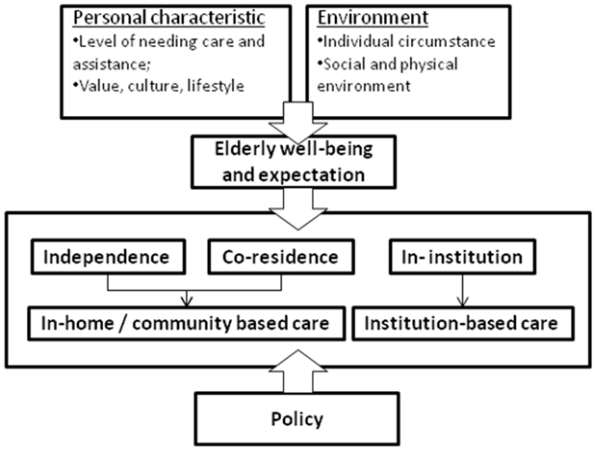

Figure 3. Elderly living arrangement and care pattern selection

Consequently, the elderly living arrangement and care pattern selection module is designed to clarify the relationships between individual elderly, the living circumstance, and related policies. This module will illustrate, and to what extent, the relationship and related policy will impact the well-being or expectation of the elderly and induce them to choose a certain kind of living arrangement and corresponding senior care (See Figure 3).

3.4 Residential moving of the elderly

As a result of limited mobility, frailty or other physical/mental health problems, many elderly require long-term care, including in-home care, community-based care, and institution-based care, as well as a more supportive living environment (See Table 2). Therefore, according to the different demands of the physical/social environment and senior services available, large numbers of elderly choose to relocate.

Borup (1983) identified four types of elderly relocation: type 1) inter-institutional (for example, from hospitals to nursing facilities, and continuing care retirement communities); type 2) residential (moving from one residence to another); type 3) residential or institutional (such as from home to a residential aged care facility); and type 4) intra-institutional (for example, movement within the facility). Wiseman and Roseman (1979) categorized local movement into six types: suburbanization, inner city relocation, apartmentalization, communalization, homes of kin, institutionalization. The simulation of seniors' migration is complicated as it refers to long-term decisions, impacted by several factors, especially, aspects of the individual's life course and the perceived benefit of alternatives. Based on the study of different relocations by Borup (1983) and Wiseman and Roseman (1979), it is suggested that when a senior decides to move, the alternative places are limited to other local communities (for example, nearby communities and relatives' homes), and residential care facilities.

3.4.1 Relocation module

The majority of elderly people prefer to age in their own home or in a relative's home. The aim of this module is to simulate the senior's migration to other communities. Because elderly people are usually long-term in-home residents, there is an importance placed on the provision within communities of senior's physical/social environment (for example, outdoor areas, transportation, dwelling conditions, social participation, social inclusion, etc.) and daily social services (for example, the service provided by a seniors' center, meal delivery service, information and referral service, home care and health care, protective services, etc.).

The classic migration decision models (for example, the push-pull model, stress-threshold model, spatial equilibrium model, and human capital/cost-benefit models, behavioral model, location-specific amenities model, etc.) tend to clarify the complicated process of decision-making (Gregory et al., 2009; Northcott & Petruik, 2011). Wiseman (1980) made use of the concepts of "push" (for example, physical decline or death of a spouse, and environmental pressure) and "pull" (for example, the therapeutic landscape in a community, relocated relatives), which were defined as "triggering mechanisms" impacted by a seniors' endogenous factors (for example, personal attributes, neighborhood ties) and exogenous factors (for example, cost of care and housing). In the spatial equilibrium model and cost-benefit model, the elderly migrate through seeking housing locations with a maximizing utility (Rudzitis, 1979) or the largest least-cost benefit. The behavior model emphasizes the individual's belief, attitude, and perception, which influences the evaluation of their dwelling and neighborhood. Their ability to obtain access to health and social welfare services (such as the socio-economic stratification, health status, and housing status) is a strong indicator of migration (Golant, 1979; Fokkema & Van Wissen, 1997). De Jong (1999) argues that the decision-making should be based on the balance of five parts: demographic factors, social networks, values and expectations, residential satisfactions, and behavioral restrictions, which underpin intentions of migration. The location-specific approach argues that relocation is a result of a change in demand for location-specific amenities, which can only be satisfied by moving to elderly desirable sites or places (Rudzitis, 1979).

Some studies conclude that besides ageing in specific places, seniors rather prefer to age near those places by moving, for example, to other nearby communities within the same city/town/village (Northcott & Petruik, 2011). Focusing on the different levels of desirability of suburbs and central cities, the order of preference for elderly movers was first to the suburbs, followed by nonmetropolitan areas, with the central city as a distant third (Golant, 1979). However, a minority of elderly people were attracted to the central city due to the convenience of public transportation and ease of access to a wide range of urban facilities that addressed the needs of the elderly, as well as the availability of smaller-sized, less expensive rental accommodations and a relatively low cost of travel, and more attractive social situation (Golant, 1979).

In other studies, the proximity of elderly people to relatives (Chai, 2010; Fokkema & Van Wissen, 1997; Longino Jr, Perzynski, & Stoller, 2002; Warnes, 1993), and the therapeutic landscapes in their living environment were specifically emphasized (Andrews & Phillips, 2005). Cuba (1991) found that individuals may repeatedly spend their vacations at the locations that eventually become their retirement places.

According to a review of research on elderly relocation, the most important process in this module is observing how an individual senior will find the location that maximizes utility having comprehensively considered other factors, such as the various attributes of seniors, the advantages of alternative locations, the impact of relatives, and so on, as well as by comparing the original location and new location - specifically the extent to which the new location offers an improvement.

3.4.2 RACF choice module

When the elderly become disabled, they usually need to make an environmental modification to preserve their independence (Litwak & Longino Jr, 1987; Longino Jr et al., 1991). Although ageing in place is always the preferred pattern, daily activities are an insurmountable barrier to this for the disabled elderly due to narrow doorways, stairs, etc. Alternatively, they may opt for relatively expensive meal deliveries and in-home nursing care. Not all elderly voluntarily age in place, where some may prefer to move, but lack the requisite resources, and can be viewed in this respect as "blocked movers" (Moore & McGuinness, 1997).

Therefore, this module focuses on the elderly who decide to migrate to an RACF, and simulates which or what kind of facility is selected from options such as nursing homes and continuing care retirement communities. Because of the different life histories, family structures, income, education, and hukou (in China), socio-economic and cultural diversity are the essential distinguishing features of the individual seniors, and will impact significantly upon the perception, evaluation, preference, and selection of RACF (Shapiro & Tate, 1985).

Firstly, according to the service contents, location, business size (large or small), profit or non-profit, and type (public, voluntary, private) of the RACF, residential care, such as assisted living, nursing home, or continuing care retirement, is a discrete category. This makes the individual's selection of an RACF a complicated choice.

Cheng et al. (2012) analyze the accessibility of residential care facilities seniors to. They suggest that geographical access, information access, economic access, socio-cultural access, and the socio-managerial environment are the primary factors influencing elderly people and their family members' decision-making process for the selection of RACF. The study on the preference of urban elderly for care facilities, conducted by Gao, X. L. (2013) on Beijing, China, points out that about 40% of elderly people prefer public facilities, and 70% prefer facilities of which the monthly expenditure is no more than 2000 RMB. As Barnes (2002) suggests, there are two types of assessment tools that can be applied to assist elderly to select their preferred facility. The first type is the multiphasic environmental assessment procedure (MEAP), which focuses on physical and architectural features of a physical facility (for example, community accessibility, physical amenities, social and recreational services, and safety), staff characteristics, and the social environment (Barnes, 2002; Moos & Lemke, 1979); the second type is the assessment tool specifically for dementia care settings, such as the professional environmental assessment protocol (PEAP) and therapeutic environment screening survey (TESS-NH) (Barnes, 2002). Focusing on MEAP, the Sheffield Care Environment Assessment Matrix (SCEAM) was provided, which emphasizes several architectural elements, such as location, outdoor space, building form, bathrooms and toilets, and private rooms, (Parker et al., 2004).

There are also other concepts related to RACFs that are developed within the field of environmental gerontology, which are “place”, “home”, and “being at home”. These are presented as other important factors for the selection of RACF. Places are more than environmental contexts to be modified when the elderly become frail; they are holistic, dynamic, and meaningful entities with histories and evolutionary trajectories with which seniors have intimate relationships and on which they depend. Therefore, in assisted living environments, the relationship between the new RACF and home is highlighted and referred to as “connectedness” (Cutchin, 2013; O'Shea & Walsh, 2013).

Therefore, the precondition for successful elderly relocation to an RACF is the match between individual preference and the specific facility. The selection of RACF is related to the service levels, staff, and the physical environment of the facilities (for example, the natural landscapes, building design, and amenities), and is influenced by the health status and socio-economic attributes of seniors. Based upon the overwhelming evidence from the existing studies, this module will emphasize the elderly preference first, and then will use one MEAP to simulate the RACF selection decision-making process.

4. BEHAVIOR OF FACILITY AGENTS

The living environment refers to the physical/social environment and senior services, and it includes two kinds of essential facilities, the day care center and RACF, which are closely related to their health care services. Therefore, the day care center and RACF are selected as the agents in this simulation. They will be simulated through four modules, the day care center business cycle module, the day care center location module, the RACF business cycle module, and the RACF’s location module. Given the scope limitations of this paper, we take the RACF as an example to introduce the simulation of the business cycle and RACF location.

4.1 RACF’s business cycle module

The business of RACFs refers to the provision of services and the revenues generated by the provision of services to target customers. Meanwhile, there is the cost of business, such as the costs of materials, labor, and equipment. Therefore, based on the profit, the business will continue to operate or become bankrupt. As for not-for-profit RACFs, the continuation of their business depends on whether the revenue that covers their expenses is acquired through the government or through donations. This module will simulate the RACF business cycle (see Figure 4), which influences the system of urban senior services provision.

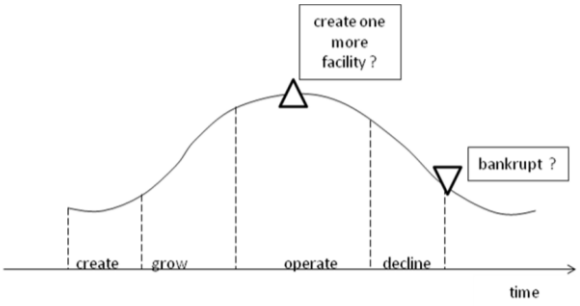

Figure 4. The business cycle of RACF

In most countries, there are acts, codes, and standards on senior services implemented by local authorities. In the United Kingdom, *Home Life: a code of practice for residential care* (UK Centre for Policy on Ageing, 1984), was the first code of practice which concentrated on care standards, residents' rights, privacy and financial affairs, facility administration, physical features, and staffing. After that there were policies such as *A Better Home Life: a code of good practice for residential and nursing home care* (UK Centre for Policy on Ageing, 1996), and *Fit for the Future? National Required Standards for Residential and Nursing Homes for Older People* (UK Department of Health, 1999), which mainly focused on health and personal care, daily life and social activities, accessibility, evaluation of care and cost, complaints procedures and protection, environmental standards, staffing requirements and standards, and management and administration standards (Andrews & Phillips, 2005). Therefore, policies for protecting the older residents significantly emphasized the regulation of quality, accessibility and cost of care.

Research on RACF businesses following the legislation of the above documents indicated that some RACFs have recently had to close due to their inability to meet the new standards (Andrews & Phillips, 2005). Many private facilities will have to reduce their capacity and may face financial difficulties to meet the new standards. It showed that poor financial and quality performance prior to the implementation of the new standards increased the risk of failure, while a larger size decreased the likelihood of performance failure (Andrews & Phillips, 2005).

The business cycle of an RACF is related to the demands of the elderly on the number of care places. For example, in Beijing, policies on the development of social senior services suggest the social senior services system is characterized as "90/6/4", which indicates that 90% of old people will rely on in-home care, 6% on community care, and 4% on residential care by 2015 (Beijing Municipal Bureau of Civil Affairs, Beijing Municipal Commission of Development and Reform, & Beijing Municipal Commission of Urban Planning, 2008). This means the demand for the number of RACFs will increase to between 140,000 and 160,000 by 2015. In Australia, there is a national target level of 113 care places per 1000 persons aged 70 years and over, which includes targets to meet the needs and preferences of care recipients. In the allocation of RACFs under the aged care policy, prospective RACFs are required to make places operational within two years, failing which the applying facility must apply for an extension (Australian Institute of Health and Welfare, 2012; Department of Health and Ageing, 2006). The RACF allocation approach was therefore put into practice through the projection of the older population and the allocation processes being well-controlled by certain policies.

This shows that the important factors within the business operation of an RACF include its health care, place, cost, and accessibility. The influence of policy on RACFs will be emphasized in this module. The main simulation process should include two parts, such as service positions, business size increase or decrease, and finally the decision over whether or not to create the new facility or close the RACF.

4.2 RACF's location module

This module is conducted to simulate how the RACF agents choose a location, and which factors are essential indicators for the decision of the

RACF. These will influence the availability of RACFs to seniors, and the selection of RACFs.

The location of an RACF is impacted by several factors. Public or private facilities have distinct distributions. Early research identified that historical influences and the varying policies of local governments are primary factors for the spatial variation of public facility provision (Andrews & Phillips, 2005). The existing studies on private RACFs suggest that funding changes, management decisions, and local planning influence the location of private RACFs (Phillips & Vincent, 1988). Demographic and socio-economic differentiations across areas influence the distribution of residential aged care facilities. The concentration and affluence of the local aged population are reliable predictors of location of both public and private RACFs. According to an interview conducted by an urban planner in Shenzhen, China, the expected distribution of RACFs is significantly related to green space, medical services, suburbs, and residential land (Shenzhen Urban Planning and Land Resources Committee, 2013).

Location selection of RACFs involves urban land use planning. The *Code for Planning of City and Town Facilities for the Aged in China* specifies the basic principles of location selection. RACFs should be adjacent to areas with high densities of elderly, hospitals, and parks, and located in natural and sunny environments. The land should be flat and well-ventilated. Infrastructure and transportation should be convenient, and removed from the highway, heavy traffic intersections, pollution sources, and dangerous goods (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2007).

The location selection process of the RACF is relevant to senior services planning, which confirms the target level of RACF places (for example, four places per 100 persons in Beijing) to ensure an adequate supply of care places and to achieve equitable access to services between the city center, and suburban and rural areas. Then, according to the number of places planned in different regions, the government or private investors make the decisions about operating the RACF and choosing its location. Land can be acquired in three different ways, as land from previously bankrupted RACFs, land that can be repurposed from its original use (for example, industry land, commercial land, or land used for infrastructure), and new land, which is allocated according to the principles of RACF location selection, such as under the *Code for Planning of City and Town Facilities for the Aged in China*.

5. ENVIRONMENTS AND THEIR INTERACTION WITH THE AGENTS

As mentioned above, the living environment is linked significantly with seniors' lives. The World Health Organization (WHO) uses the concept of the age-friendly city, which provides a detailed description of age-friendly environments (World Health Organisation (WHO), 2007). Age-friendly cities are defined in eight parts which overlap and interact with each other (See Figure. 5).

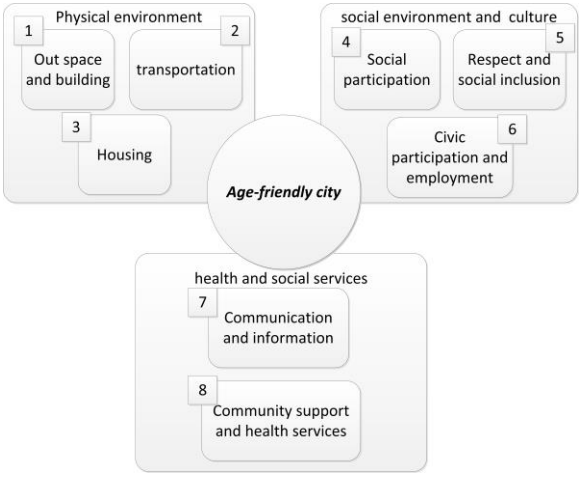

Figure 5. Age-friendly city framework of WHO

Outdoor spaces and buildings, transportation, and housing are key features of a city's physical environment. The social environment affects the mental well-being of seniors. Health and social services are offered for the promotion, maintenance and restoration of health (World Health Organisation (WHO), 2007). Therefore, the living environment plays a fundamental role in the daily lives of the elderly, especially for seniors who are ageing at RACFs. Many social geographers, urban planners and architects have done further studies on specific enabling environments, such as barrier-free environments, parks, and recreational settings for the elderly (Carp & Christensen, 1986; Kaplan, R., 1985; Phillips et al., 2005; Rosenberg, 1998). In addition, different types of neighborhoods are characterized by location, environmental quality, access to services and facilities, and residential density. Seniors living in different neighborhoods have significantly different socio-economic attributes and behaviors (Knox & Pinch, 2000; Chai, 2010; Wu, F. L., 1992). They will also make discriminating assessments on different dimensions of seniors' living environments (Cunningham & Michael, 2004; State Advisory Council on Aging, 2007). Therefore, the enabling environments in different neighborhoods should be diverse.

In this simulation, the input of the environment should primarily include the physical environment, social environment, health services, and the urban distribution of different types of neighborhoods. According to the environment parameters (for example, the number of bus stations, size of outdoor spaces, etc.), and the agent evaluation indicators (such as an elderly person's accessibility or satisfaction), the interactions between agents and environments are built. The statistical report of these factors provides a method to support the systematic allocation of infrastructure or facilities and the urban planning of age-friendly cities. The urban policy is an essential aspect of the environment as well. It includes direct policies, such as the social senior service policies, and indirect policies, such as social security system policies and household registration policies. The critical contents of these policies will be selected and translated into the parameters that are important for the rules governing agents or the interactions between agents or between agents and environments.

6. INTEGRATED SIMULATION AND DISCUSSION

The ECSS Model includes three simulation parts: 1) several simulation modules, 2) the section of the database and data input, and 3) the definition of output reports. The simulation modules are related to elderly population, urban environment, and external factors. The integration of the micro simulation modules of the ECSS Model is shown in Figure 6. Through inputting the data of individual elderly, day-care centers, RACFs, and other environmental facilities in simulation modules, changes and transitions of different agents are processed according to their behavior rules as this paper has introduced above.

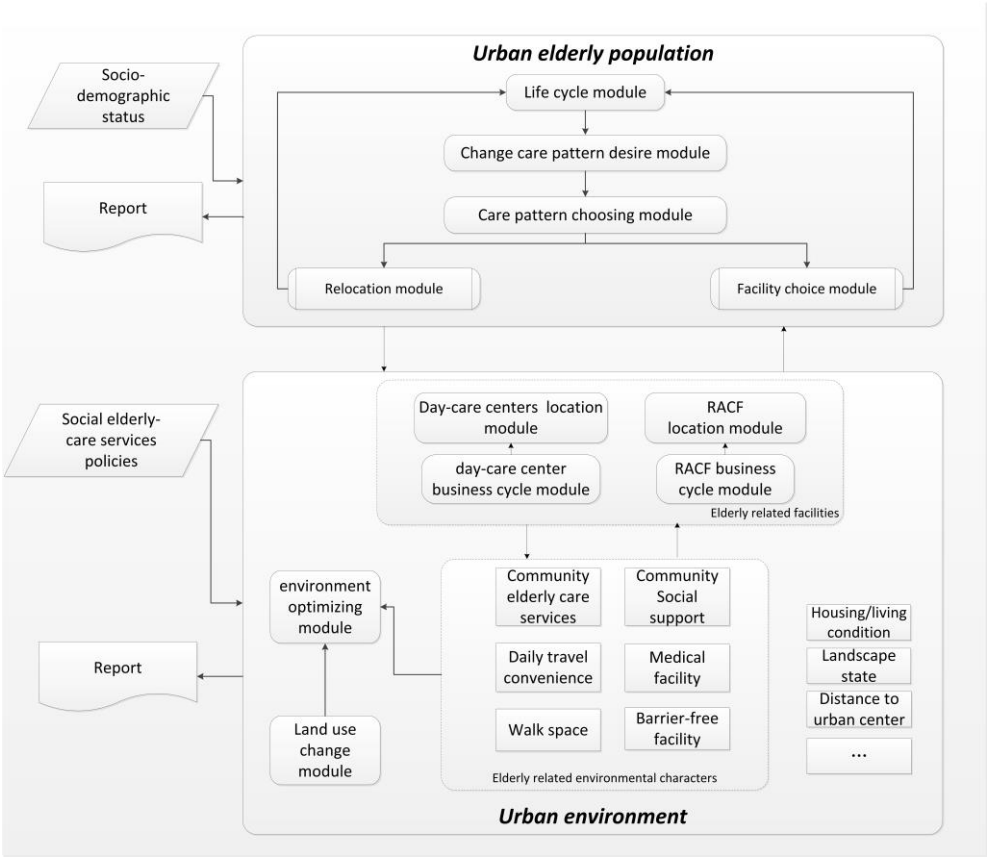

Figure 6. Urban elderly population and environment change processes and micro simulation modules

With the agent-based modelling (ABM) approach, there are several platforms that can be used to integrate the agents, modules, and interactions, and to simulate the complicated processes. The platforms now widely used are MASON, NetLogo, Repast, and the Java and Objective-C versions of Swarm. NetLogo is the highest-level platform of these, providing a simple but powerful programming language, with built-in graphical interfaces and comprehensive documentation.

The expected results include two parts, which are the prediction of senior services and the improvement of senior service provision. Regarding the prediction of senior services, the behavior of the elderly within their life cycle courses, the living environment evaluation, the probability of living arrangement changes, and the decision-making process for relocations are imported into the corresponding modules in each simulation cycle. Consequently, the aged population and service needs will be forecast. Based on this, RACFs and their places are provided, and the adjustments to the age-friendly environment in different spaces are conducted. These changes

will then impact on the business cycle of facilities and the whole social care system, which will be further regulated by the governance factors. Therefore, by focusing on the individual behavior, micro-space and the dynamic change of agents, the prediction accuracy of this study will improve upon previous research.

In view of the uncertainty of various policies, different policy-scenarios are designed, which are entirely differentiated from the traditional approach known as survey-analyze-plan or SAP. The provision of social senior services will be simulated accordingly, and the suitable long-term provision plan will be determined.

This study is one of the first studies to design a simulation framework that models the demand-supply of senior services with MAS. The findings will be a great support to the provision of elderly service facilities and environmental improvement in urban neighborhoods. The reasonable provision of aged services will be extremely important to the rapidly ageing society and developing countries as capital and resources are limited. The approach of this study (simulation, scenario analysis) is especially useful for urban planning; however, it has limitations in terms of the selection of agents: in actuality, for example, the relatives or children of the elderly play an important role in seniors' lives, even though the impacts do reduce gradually. The programming of children as agents was not possible due to the lack of available data. Due to the nature of cross-disciplinary studies, the diversity of urban policies, and the complicated external environment, the rules and interaction of agents, and the quantitative set of the external impacting factors, are difficult to consider comprehensively, which may be a source of potential errors. In the future, these areas should be further studied and the methods refined.

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