



Locating Community-Based Comprehensive Service Facilities for Older Adults Using the GIS-NEMA Method in Harbin, China

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Abstract: Local governments and scholars in China have recently proposed and developed *community-based comprehensive service facilities for older adults* in response to population aging and greater service needs of older adults in urban areas. This study proposes a method to identify the ideal distribution of such facilities by combining the nested ecological model of aging in place as the theoretical foundation with a geographic information system as the methodological tool. The findings indicate that many essential services, particularly health care and places for socialization, are lacking in urban areas when walkability and accessibility to public services are considered. The findings also indicate that the downtown and main factory areas with higher population density have a higher need for developing community-based comprehensive services facilities for older adults. The proposed method shows strong potential for locating service networks and provides useful information for policy development, urban planning, and architectural programming. DOI: 10.1061/(ASCE)UP.1943-5444.0000678. © 2021 American Society of Civil Engineers.

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Introduction

Care for older adults in China has been traditionally informed by the Confucian ideal of respect for the elderly and filial piety, thus heavily relying on family caregiving while keeping the state's role at the minimum (Shea and Zhang 2017; Liu and Kendig 2000). However, such a configuration has been seriously

challenged in recent years. At a macro level, the aging population, which was spurred by the now-defunct one-child policy, still has a strong effect, and the unprecedented urbanization and migration across China make it impractical to adhere to the family as the major source of caregiving. At a micro level, the weakening of intergenerational ties and filial obligations of adult children to their elderly parents has been extensively documented (Shea and Zhang 2016). In response, “aging at home with community-based services (社区居家养老 shè qū jū jiā yǎng lǎo)” has become one of the most strongly promoted policies at all levels of Chinese governments (Yao 2018; Ma et al. 2018). Such policies well align with the current trends that more than 95% of Chinese older adults remain in their homes and communities (Jiang et al. 2018). However, scholars have pointed out that the resource allocation for aging-in-place care services in urban area has been uneven and inadequate (Cao et al. 2014; Zhou et al. 2013). It is thus necessary to examine the current age-related community services and reconfigure its distribution networks in order to deliver elder care services in the most equitable and efficient manner.

This study examines one of the current age-related community solutions promoted by the policy change called comprehensive service facilities for older adults (CSFO). First tried in Shanghai by a private institution in 2014, the CSFO model is now being adopted in multiple Chinese cities (Ma et al. 2018). CSFOs offer a variety of institutional and professional services according to older adults' every day and medical needs, and they make up the deficiency of community resources that delimits older adults' ability to conduct everyday activities (Yao 2018; Ma et al. 2018). These services at a minimum include day care or residential care for seniors but could be expanded to offer opportunities to eat, socialize, shop, or receive medical care, depending on what the surrounding neighborhood already offers. In essence, CSFOs offer services to help older adults maintain three essential components for aging in place in the Chinese urban context: (1) activities of daily living; (2) medical care; and/or (3) socialization and recreation.

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Due to CSFOs' critical functions and the way they operate within the community, their spatial distribution requires careful planning to deliver intended services efficiently and equitably. Such strategic distribution is likely to contribute not only to older adults' independence and well-being in everyday life, but also to enhance social welfare, spatial equity, and inclusion for all (Zhou et al. 2013). To ensure CSFOs are located in places where they can best serve older adults, the current study proposes a method to identify an ideal service network within a geographic boundary in order to create an aging-friendly city.

Through public-private partnerships, the city of Harbin (哈尔滨), the provincial capital of Heilongjiang (黑龙江) and China's northernmost major city, has enacted policies to increase the accessibility to social and health-care services for older adults (Harbin Municipal People's Government 2018). The city is using CSFOs to create a comprehensive series of community-based services catered to improve older adults' well-being and provide a continuum of care (Harbin Municipal People's Government 2018). The city's strong commitment to building an aging-friendly city through CSFOs, its significance in terms of GDP, population, and politics, and the authors' access to a large data set makes Harbin, China, an ideal site for a case study.

Existing research and statistics both confirm that the geographical distributions of an older population, the medical system, and social welfare agencies critically influence the ideal functioning and distribution of CSFOs (Zhang and Zhao 2017). In Shanghai, Yao (2018) identified three types of community-based services—long-term care, public services, and neighborhood commerce—and analyzed their locations, floor areas, and building orientations to offer insights on how these spaces could be converted to CSFOs. Similarly, Zhou et al. (2013) examined whether the locations of community-based services for older adults in four Beijing neighborhoods allowed for equitable service distribution. Their multicase study included private, public, and residential care facilities run by a public-private partnership.

In the field of urban planning and city development, accessing age-related services and their geographical distribution became an important topic that has received international attention. For example, Chen et al. (2020) employed a spatial analysis framework to explore the accessibility of age-restricted communities in Edmonton, Canada. Similarly, Johnson et al. (2005) used domain-specific demand forecasts and designed alternative hierarchical facility location models for senior centers in Pennsylvania. In Japan, Nishino and Kasai (2019) proposed the 2,025 and 2,040 planning schemes for the location of senior facilities in Kaga, Japan, based on the distribution of the older population using GIS. However, studies have largely overlooked community networks and the related concept of social capital that operate within the physical boundary of a neighborhood despite their potential to influence behaviors, accessibility, satisfaction, and resource. First, most of the reviewed studies do not distinguish access modes of older people (accessibility versus walkability) and do not incorporate the local service demands of aging in place, and the urban networks of existing community services. Second, studies conducted in North America and Japan exclusively focused on retirement communities and long-term care facilities, leaving out community-based services. On the other hand, studies in China tend to focus on community-based services but mostly those in first-tier and well-developed cities such as Beijing and Shanghai, excluding smaller cities such as Harbin, China. The current study complements the aforementioned studies by incorporating the concept of community network and social capital and further focusing on those services geared toward the community-living older adults in a smaller Chinese city.

The current study uses Harbin, China, as a case study to build a theoretically informed, data-driven, yet practical method for studying the geographic distribution of CSFOs. Using logics present in the *nested ecological model of aging in place* (NEMA) and operating within a geographic information system (GIS) environment, the combined theory-method, henceforth called GIS-NEMA, is designed to serve as a tool to diagnose the current service gaps and identify ideal locations for future expansion of CSFOs. The next section first discusses the theoretical framework of the nested ecological model and how it connects the three core components of aging in place and then describes the methodology and tests the utility of GIS-NEMA with multilevel data from Harbin, China.

Theoretical Framework: Nested Ecological Model of Aging in Place

The current study builds upon ecological systems theory (Bronfenbrenner 1999) and subsequent development by Shin (2014a, 2016), which underlines the physical environment as a core component of urban ecology in human functioning and satisfaction (Shin 2016; Bronfenbrenner 1999). Unlike Bronfenbrenner's original approach where the physical environment largely plays an implicit role in urban design and service provision, Shin focused on the social network connecting actors at three nested levels of a home, neighborhood, or community, and the larger ecological system within the physical space. Such explicit focus on the geographical dispersion of the social network at three levels facilitates systematic thinking in community and urban design.

Studies demonstrate the utility of ecological approaches by showing how social support at the neighborhood and city levels plays an important role in helping individuals age in place, although they do not explicitly discuss ecological theories. For example, Lehning (2012) demonstrated that a well-integrated public transportation system and accessible housing can improve older adults' well-being and help them maintain independence within the community. Researchers also demonstrate benefits community-based programs have for older adults, such as greater social involvement (Jin et al. 2018), increased mobility, enhanced ability to meet household needs, greater access to health care, reduced social isolation, enhanced home environment, and greater perceived ability to obtain assistance needed to age in place, especially for low-income, older residents (Scharlach et al. 2015).

In a more explicit use of an ecological approach to older adults aging in place, Shin (2014a, b) demonstrated that a well-developed service network and social capital within a community enabled groups of elderly immigrants in US metropolitan areas to achieve high levels of intergenerational independence, despite their inability to speak English and lack of cultural competency, skills that are often essential for independent living in the United States.

The current study further develops Shin's framework of a nested ecological system in the Chinese context of aging and community life and puts forward the nested ecological model of aging in place (NEMA). Critical components of aging-friendly communities are identified and modified based on the WHO (2007) Global Network for Age-friendly Cities and Communities. These modifications take into consideration China's contextual factors, including the country's social system, housing stock, transportation, community organization, and cultural attitudes toward older adults, and draw on China's laws on the Protection of the Rights and Interests of the Elderly (Standing Committee of the National People's Congress 2019).

The NEMA connects the modified World Health Organization components by starting with the assertion that communities need

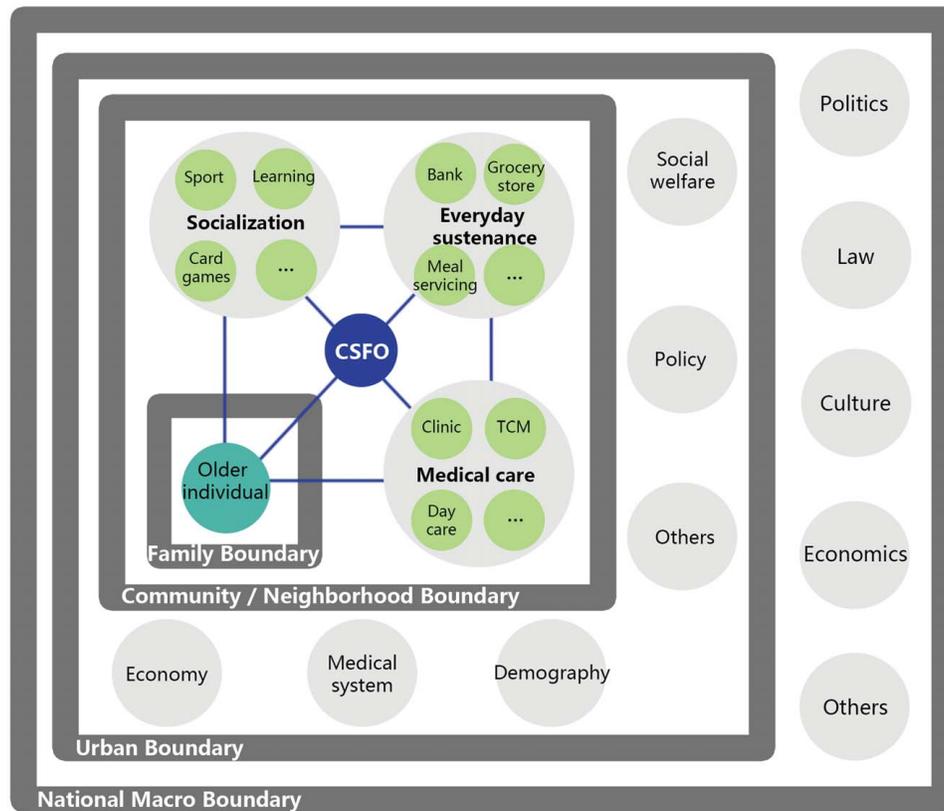


Fig. 1. Nested ecological model of aging.

to fulfill three basic needs of older adults so they can age in place: (1) everyday sustenance; (2) socialization; and (3) health care. In China, the urban older adult is nested primarily within the family, but may seek those components outside the family, perhaps through a CSFO or other service agencies, which are, like the family, nested within a neighborhood (Fig. 1).

Provision of such services should utilize existing community resources first and CSFOs can be added to fill service gaps. It is important that existing community resources and social fabric is preserved and that CSFOs are strategically added to enhance that community service network, not replace it. Maintaining one's social network and routines within one's community is essential given that individuals initiate these habits in early and midadulthood (Elder et al. 2003), and that development of such social capital takes time (Coleman 1988). Experts consider aging in place a worthy social goal in part because empirical studies find that moving to a new home in later stages of life may diminish older adults' overall sense of well-being and increase morbidity and mortality rates (Hays 2002).

As Fig. 1 shows, the coordination between CSFOs and existing community resources occurs within the larger sociopolitical system at urban and national levels, including China's social welfare and health-care systems, which are informed by changing demographics, cultural beliefs, and policies related to family and the care of older adults.

Three Critical Components of Aging in Place

The first and foremost need of older adults is maintaining daily activities for basic sustenance. This includes activities of daily living and basic self-care tasks such as bathing, personal hygiene, dressing, functional mobility, and self-feeding (Katz 1983), and more advanced, instrumental activities such as financial management, transportation, shopping and meal preparation, house cleaning,

Table 1. Critical community services for aging in place

Basic need	Services
Everyday sustenance	Community meal service Public restrooms Housework agencies Local grocery stores General merchandise stores Banks
Health	Community clinics Pharmacies Traditional Chinese medicine clinics Hospitals Day care Long-term residential care
Socialization	Community centers Parks

communication, and medications (Lawton and Brody 1969). Based on this conceptualization, these services were identified as essential for aging in place in the Chinese urban context: community meal service, public restrooms, housework agencies, local grocery stores, general merchandise stores, and banks (Table 1). CSFOs could provide some of these services. Given that Chinese cities offer quality public transit that is considered aging-friendly, public transportation was treated as a given.

Addressing the health needs of Chinese older adults is the second most important component of the model. These needs include medical care, access to conventional and alternative medicine, residential support, and daytime supervision for adults who cannot be left alone (Zhu 2015; Chen et al. 2010; Kane and Kane 2001; Ma et al. 2017, 2020). Community businesses and

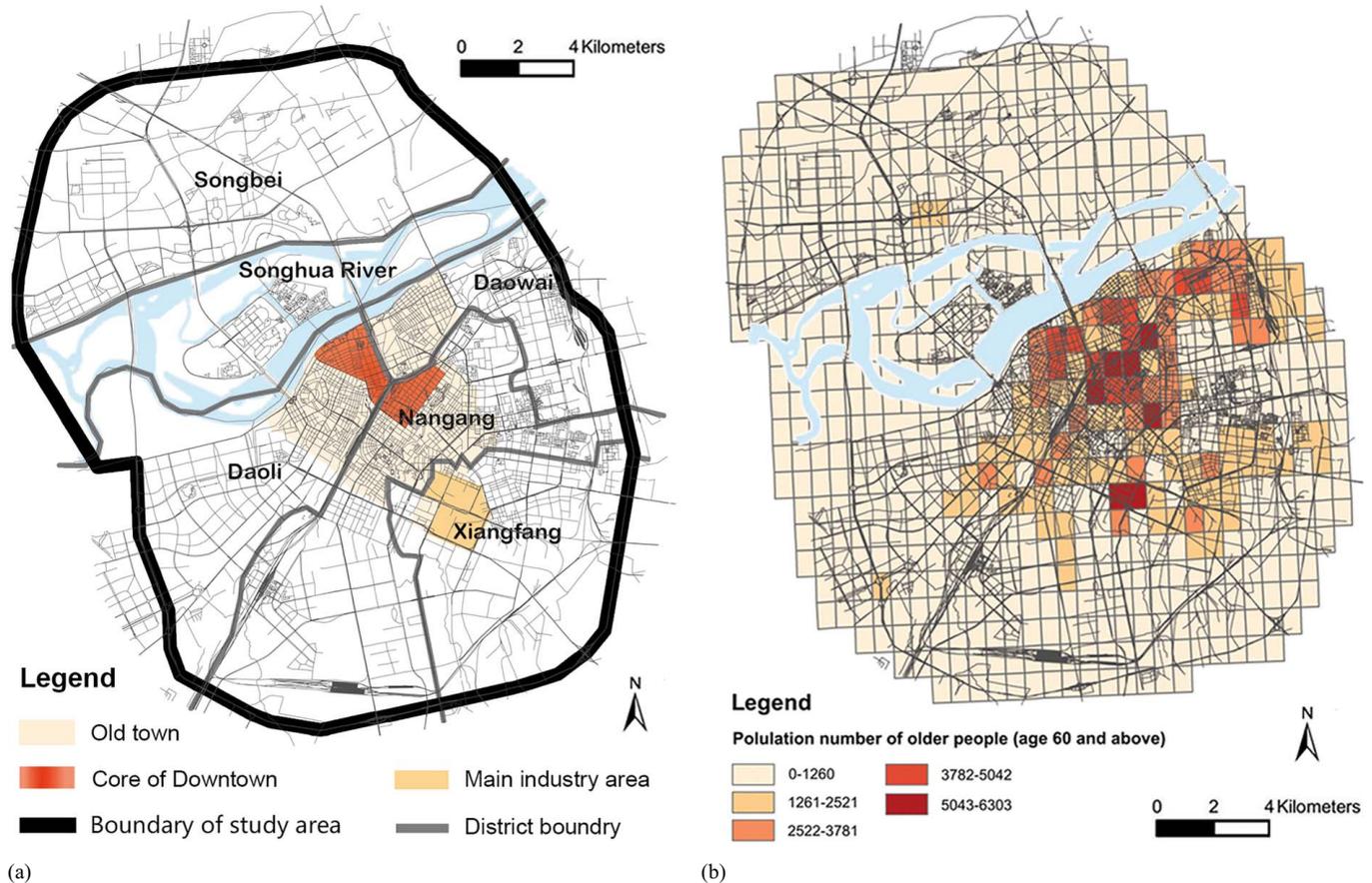


Fig. 2. Study area and older population distribution within Harbin: (a) the study area; and (b) older population distribution (F_1).

agencies that meet the demand for these services include community health clinics, pharmacies, traditional Chinese medicine clinics, hospitals, adult day care, and residential long-term care (Table 1), all of which older adults could receive through CSFOs.

Providing socialization and recreation is the third component of aging in place. Socialization and recreation are critical precursors for older adults to have an overall sense of well-being and good health outcomes. Socialization and recreation contribute to older adults' abilities to learn, grow, make decisions, build relationships, and maintain their social participation and dignity (Bowling 2008). Older adults socialize and engage in recreational activities in context-specific ways. Common threads may unify a broad Chinese culture, but older adult patterns of socialization and recreation can be drastically different, especially between rural and urban populations in Heilongjiang province (Ma and Shin 2019). Rural-urban differences, as well as diversities in regional culture and climate, need to be considered when designing services and establishing agencies to serve older adults. Given winter is extremely cold and long in Harbin, China, the nested ecological model of aging in place considers indoor (community centers) and outdoor spaces (parks). A CSFO could include a community center along with a day or long-term residential care or offer an activity in a nearby park.

Linking Mechanism

The three identified aging-in-place components should be spatially distributed to offer ready access to older adults in most parts of

targeted areas. Therefore, the following three logics were used. First, the number of service agencies from each category in Table 1 should be proportional to population density. Thus, densely populated urban areas would require a higher number of service agencies. Second, service agencies that older adults visit to utilize their services need to be within walking distance. Third, services that are designed to be delivered to older adults' homes would require a reasonable level of accessibility by car. How these logics are structured into the proposed GIS-NEMA is described in the following sections.

Methodology

Study Area

Harbin, China, serves as a key political, economic, scientific, cultural, and industrial hub of Heilongjiang. Harbin is China's eighth most populous city, overseeing nine metropolitan districts, two county-level cities, and seven counties (2016 Heilongjiang Province Administrative Divisions 2016). This study focuses on Harbin's most populous areas, the five districts of Daoli, Daowai, Nangang, Xiangfang, and Songbei, which are circumscribed by the third ring road (*sān huán*; 三环) [Fig. 2(a)].

This area was selected due to its well-developed public transit system and pedestrian networks. The old town is on the south side of the Songhua River, surrounding the city center where Daoli,

Table 2. Five levels of walkability and accessibility

Level	Walkability	Accessibility
1	Older adults: 5 min	Most accessible: 15-min walk for older adults
2	Older adults: 10 min	15-min walk for younger adults
3	Older adults: 15 min	15-min car ride (3,000 m) during high-traffic hours
4	Younger adults: 15 min	Maximum 15-min car ride 10,000 m
5	More than 15 min	Least accessible: more than 15-min car ride

Daowai, and Nangang districts intersect [Fig. 2(a)]. The city center has the highest population density and most developed commercial districts [for distribution of older adults derived from general population distribution, see Fig. 2(b)]. The old town also contains the industrial core with a high population density at the northern center of Xiangfang District [Fig. 2(a)]. The rest of the study area, particularly toward the periphery and north of the Songhua River, has a lower population density and contains newer development than the city center [Fig. 2(b)].

Data Sources

The population data were acquired from the most recent (2010) Chinese National Census. Using GIS, the five districts of Harbin, China, were divided into 629 subdistricts of equal land area and the number of adults aged 60 and older for each of the 629 subdistricts was estimated. A uniform 15.2% as the proportion of older adults throughout Harbin, China, was assumed based on the Sixth National Census Office of the State Council (2011). The proportion of older adults is not available at the subdistrict level [Fig. 2(b)].

Second, basic ArcGIS 10.6 functions were used to map the discrete units of the services listed in Table 1. These data were acquired from two sources. The locations of day and long-term residential care came from Statistics of Harbin Civil Affairs Bureau in 2017. The rest of the data were obtained from the Baidu Map's points of interest (Kang et al. 2018), which is widely used in China and functionally similar to Google Maps in the United States.

Test of Assumptions

Pearson's Correlation analysis was employed to establish whether the population density of adults aged 60 or older correlated with the spatial distribution of aging-related services. This analysis was necessary because of the assumption that each subdistrict has a uniform percentage of older adults of 15.2%. The correlation between the estimated number of older adults and the number of each service type within each subdistrict ($n = 629$) across Harbin, China, was examined. Two-tailed tests were conducted using SPSS.

Access Modes

The current study employed a location-based perspective, which assesses accessibility to target services based on the proximity from one's residential locations (Chen et al. 2020; Al-Sahili and Aboul-Ella 1992). The perspective is widely used in urban planning research. However, unlike the common GIS approach of marking a simple radius around an agency to estimate its service area, the current study ranked the walkability and accessibility of current community-based services depending on their service delivery mode (Table 2). For those agencies that older adults visit to receive their services, a walkability range that reflects how

long it would take for an older adult to walk from their home to an agency or a service was identified (Van Holle et al. 2014). The walkability range reflects actual patterns of pedestrian behaviors better than a simple radius because certain urban features such as major thoroughfares can limit actual travel (Leslie et al. 2007). As a result, the walkability ranges tend to appear as noncircular shapes on the map, often modified by the presence of various urban features, most notably, highways and major thoroughfares. For the present study, a five-level scale was developed assuming the average walking speed of Chinese older adults at 0.9 m/s (Zhang et al. 2009). A 5-point accessibility scale was also used to determine the accessibility of housework agencies, hospital ambulances, and other services typically delivered to an older adult's home. Accessibility is assessed based on the travel time by car (Ford et al. 2015).

Gap Analysis to Determine Need for New CSFOs

The first step to determine the need for new CSFOs was identifying areas where existing agencies leave a gap in services due to lack of walkability or accessibility. A set of factors were employed, each associated with the degree of demand for service by older adults based on the existing literature. The factor weight from the degree of demand was then derived.

Walkability and accessibility are rated 1–5 with 1 indicating the greatest ease of walkability and accessibility. The preliminary analysis revealed that the study area has sufficient numbers of local grocery stores, general merchandise stores, banks, and pharmacies when measured by walkability and a sufficient number of housework agencies when measured by accessibility. Therefore, these services and facilities were excluded from subsequent analyses. For analyses of different cities where these facilities are not sufficiently provided, these services should be included. The following list shows factors included in the final analysis:

- Factor 1 (F_1): Number of adults aged 60 or older from each subdistrict, rated into levels of population density 1–5 respectively, with larger numbers indicating higher numbers of older adults. The demand degree is set at 100% to ensure full consideration of population characteristics.
- Factor 2 (F_2): Hospital accessibility. The demand degree is set at 100% to account for the critical importance of hospitals in old age care.
- Factor 3 (F_3): Walkability to parks. The demand degree is set at 64.5% according to a survey of 167 older persons in northeastern China (Ma et al. 2017).
- Factor 4 (F_4): Walkability to CSFOs, or day, residential, or mixed care. The demand degree is set at 100% to account for CSFOs' comprehensiveness and the critical importance of health-care services in old age care.
- Factor 5 (F_5): Walkability to community health clinics. The demand degree is set at 81.5% according to the survey by Ma et al. (2017).
- Factor 6 (F_6): Walkability to community centers. The demand degree is set at 49.2% according to the survey by Ma et al. (2017).
- Factor 7-1 (F_{7-1}): Walkability to public restrooms. The demand degree is set at 20% based on the estimate that 20% of older adults have incontinence (Vogel 2001).
- Factor 7-2 (F_{7-2}): Walkability to traditional Chinese medicine clinics. The demand degree is set at 40% based on finding that traditional Chinese medicine clinics issue 40% of prescriptions in urban settings (Qi et al. 2011).

- Factor 7-3 (F_{7-3}): Walkability to community meal services. The demand level is set at 67.7% according to the survey by Ma et al. (2017).
Next, the factor weight was determined by the demand degree of the factor divided by the sum of demand degree of all factors (Table 3):

$$W_{Fi} = \frac{D_{Fi}}{\sum_i^n D_{Fi}} \quad (1)$$

where F_i =factors that influence potential locations of CSFOs, $i = 1 \sim n$; i is the index of factors, n is the total number of factors; W_{Fi} =weighted importance of each factor, the higher the more important; and D_{Fi} =demand degree of each factor, expressed as a proportion of older adults, indicating the importance of each individual service.

Next, the factor weights in Table 3 were used to identify ideal locations of three types of CSFOs (day care, residential, and mixed), using three strategies (addition of buildings, converting community health clinics, and converting community centers), to develop nine hypothetical scenarios. All nine scenarios depend on the day or residential or some other mix of agency involving health-care services already existing in the area. Because day-care and residential CSFOs have different patterns of usage, the

Table 3. Weight for different factors that relate to CSFO distribution

Factors in GIS analysis (F_i)	Demand degrees (D_{Fi}) (%)	Factor weights (W_{Fi}) (%)
F1: Population density	100	16
F2: Hospital accessibility	100	16
F3: Park walkability	64.5	11
F4: CSFOs, day care, residential care, or mixed care walkability	100	16
F5: Community health clinic walkability	81.5	13
F6: Community center walkability	49.2	8
F7-1: Public restrooms walkability	20	3
F7-2: Traditional Chinese medicine clinics walkability	40	6
F7-3: Community meal services walkability	67.7	11

locations of existing day-care centers were factored in. Thus, locations for new day-care CSFOs and residential care CSFOs were identified using the formula below:

$$PL \text{ of DC or RC COSFs} = \sum_i^n W_{Fi} \times L_{Fi} \quad (2)$$

where PL of DC or RC CSFOs = potential locations of day care and residential pattern CSFOs; W_{Fi} =weight of each factor, $i = 1 \sim n$; i is the index of factors, n is the total number of factors; and L_{Fi} =walkability or accessibility levels of each factor, scaled 1–5 (Table 2).

For the ideal locations for the mixed CSFOs, the locations of both existing day-care centers and residential services were taken into considerations using the formula below:

$$PL \text{ of mixed COSFs} = 50\% \times PL \text{ of DA COSFs} + 50\% \times PL \text{ of RC COSFs} \quad (3)$$

where PL of mixed CSFOs = potential locations of mixed pattern CSFOs; PL of DA CSFOs = potential locations of day-care pattern CSFOs; and PL of RC CSFOs = potential locations of residential care CSFOs.

Next, a weighted overlay method within GIS was used in order to model the suitability of areas for future CSFOs. To this end, a suitability scale of 1–5 was developed with 5 indicating the greatest suitability using the following four logics:

- Logic 1: CSFOs should be close to urban amenities listed in Factors 2 and 3.
- Logic 2: the number of CSFOs should be proportional to the density of older adults in the area (Factor 1).
- Logic 3: Newly constructed CSFOs should be distant from existing facilities and services listed in Factors 4–7.
- Logic 4: CSFOs that are converted from community health clinics or community centers should remain in close proximity to existing community health clinics or community centers (Factor 6) in addition to fulfilling Logic 3.

The main framework and method of the current study are shown in Fig. 3.

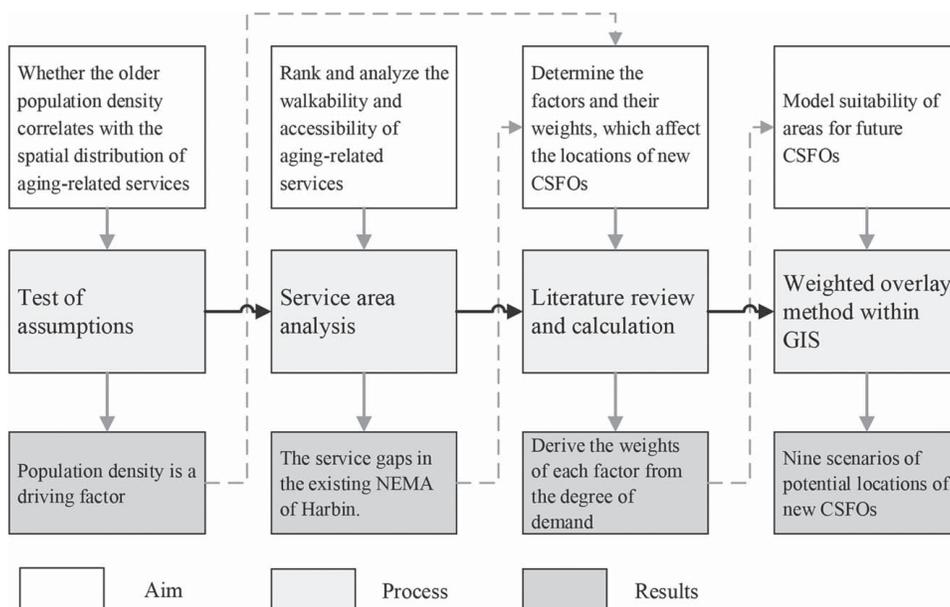


Fig. 3. Main framework of the current study.

Results

Current Facilities

Population Density and Current Service Facilities

The result from the correlational analysis of the population density of older adults in each of the 629 subdistricts and the distribution of each type of facility or service across Harbin, China, reveals a generally positive relationship, meaning that the greater the population density of older adults, the more service facilities are in a given area.

The spatial distribution of general merchandise stores, pharmacies, and banks were strongly correlated with the population density of older adults (Pearson's $r=0.68$, 0.67 , and 0.64 , respectively). The distribution of local grocery stores and public restrooms were moderately correlated with the population (Pearson's $r=0.50$ and 0.43 , respectively). The following facilities were moderately correlated: community meal services ($r=0.33$), community clinics ($r=0.32$), housework agencies ($r=0.30$), acute care ($r=0.30$), traditional Chinese medicine clinics ($r=0.29$), community centers ($r=0.27$), residential care facilities ($r=0.27$), and parks ($r=0.21$). Finally, the distribution of day-care facilities for older adults showed a modest correlation with the population density (Pearson's $r=0.12$). Except for day-care facilities, all correlations were significant at the 0.001 level (two-tailed). The correlation between day-care facilities and the population density was significant at the 0.005 level (two-tailed).

Service Gap Analysis

The GIS analysis result indicates that many essential facilities for aging in place were more than walking distance from the homes of a significant portion of older adults in Harbin, China. The services that were within a 15-min walk of an older adult's home were general merchandise stores, banks, and pharmacies [Figs. 5(a, c, and d)]. Hospitals and housework agencies demonstrated acceptable levels of accessibility [Figs. 4(a) and 5(e)].

The distribution of community meal services [Fig. 4(c)], public restrooms [Fig. 4(b)], and local grocery stores [Fig. 5(b)] was less than ideal, with a significant portion of older adults in the study area not having ready access to these facilities. However, older adults had access to groceries because, in China, general merchandise stores carry them, and such businesses were within walking distance of a large share of older adults' homes.

Community health clinics, traditional Chinese medicine clinics, and day and residential care facilities were evenly distributed throughout Harbin, China, and the distribution was proportional to the population density of older adults. However, many urban areas were left uncovered when measured by walkability [Figs. 4(d–g)]. Residential care facilities were not ideally distributed and were mainly clustered around the east side of the city where the land price is relatively low, leaving the main industrial and downtown commercial areas with higher population densities of older adults without sufficient residential care facilities.

Parks were mainly clustered around new urban districts—the west of Daoli District and the middle south of Xiangfang District—while leaving older adults in downtown areas deprived of opportunities for outdoor socialization [Fig. 4(i)]. Community centers showed the reverse and were mostly clustered around the urban center where property values are high [Fig. 4(h)].

In sum, the correlational analysis supports the assumption on the distribution of older adults, and the subsequent GIS analysis

provides an overview of the existing service network across Harbin, China. By clearly identifying gaps for each type of facility, the proposed GIS-NEMA then could be used for identifying the ideal distribution of essential facilities for aging in place in Harbin, China.

Potential Location of New CSFOs

The study developed nine scenarios for filling service gaps [three methods of addition (new construction, converting health clinics, converting community centers) \times three types of CSFOs; Figs. 6–8]. The suitability of CSFO locations is rated on a 5-point scale, where 5 indicated most suitable.

The distribution of potential sites for newly built CSFOs was similar among day care, residential, and mixed facilities. Apart from the downtown area, nearly a third of Harbin, China, was considered suitable for new CSFOs at the suitability level of 4 [Figs. 6(a–c)]. Potential sites for new CSFOs at suitability level 5 were exclusively located near the main industrial area and downtown [Fig. 6(d)]. New construction of day care and mixed types of CSFOs were particularly suitable along the south side of Songhua River [Figs. 6(a–c)].

The high concentration of community health clinics along the south side of the Songhua River provides the most suitable ground for conversion into CSFOs. However, only one clinic located downtown reached the suitability of 5 for converting to day care and mixed pattern CSFO [Fig. 7(d)]. In addition, most clinics south of downtown were deemed suitable for converting to any of the three types of CSFO. The north side of downtown showed rather heterogeneous results: health clinics in the middle section of northern downtown are suitable for converting into residential CSFOs, whereas those on the east and west sides were deemed suitable for converting into day care and mixed-use pattern CSFOs [Figs. 7(a–c)].

The south side of the Songhua River again provided the most suitable ground for converting community centers into CSFOs with suitability levels of 4 or 5. Of the three types, the mixed CSFO demonstrated the highest suitability, followed by day care, then long-term residential care (Fig. 8).

Discussion

In addition to mapping the population density of older adults in Harbin, China, the analysis reveals two distinctive patterns in the distribution of current CSFOs: (1) the service economy is a driving factor in the current distribution of aging-related services; and (2) different levels of public amenities are linked to different stages of urban planning in China.

Population Density and the Service Economy as Main Driving Factors

While the analysis revealed that population density was the most obvious driving factor for the distribution of service facilities, it shows that services that were less regulated by Harbin's government, more profitable, and backed up by the city government were well distributed throughout Harbin, China. These services included banks, grocery stores, and pharmacies.

Among all services, day-care facilities seemed to be the most lacking, due mainly to low profitability and lack of support from the municipal government. Residential care facilities were also lacking, especially around the city center in Daoli and Nangang districts, potentially due to exorbitant land prices (for a similar case in

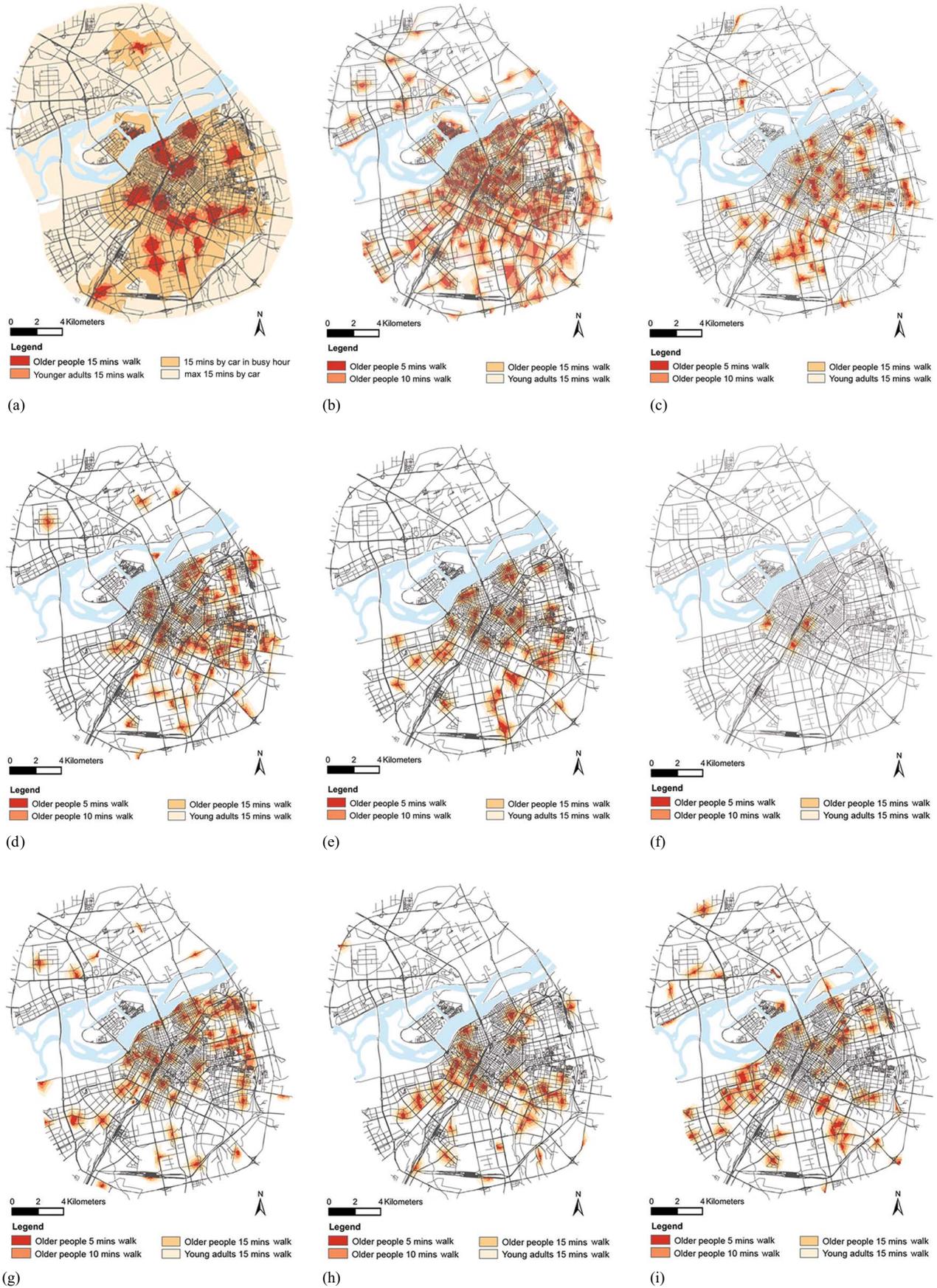


Fig. 4. Walkability of current insufficient facilities and accessibility of hospitals: (a) hospitals (F_2); (b) public restrooms (F_{7-1}); (c) community meal service (F_{7-3}); (d) community clinics (F_5); (e) TCM clinics (F_{7-2}); (f) day-care facilities (F_{4-1}); (g) residential care facilities (F_{4-2}); (h) community centers (F_6); and (i) parks (F_3).

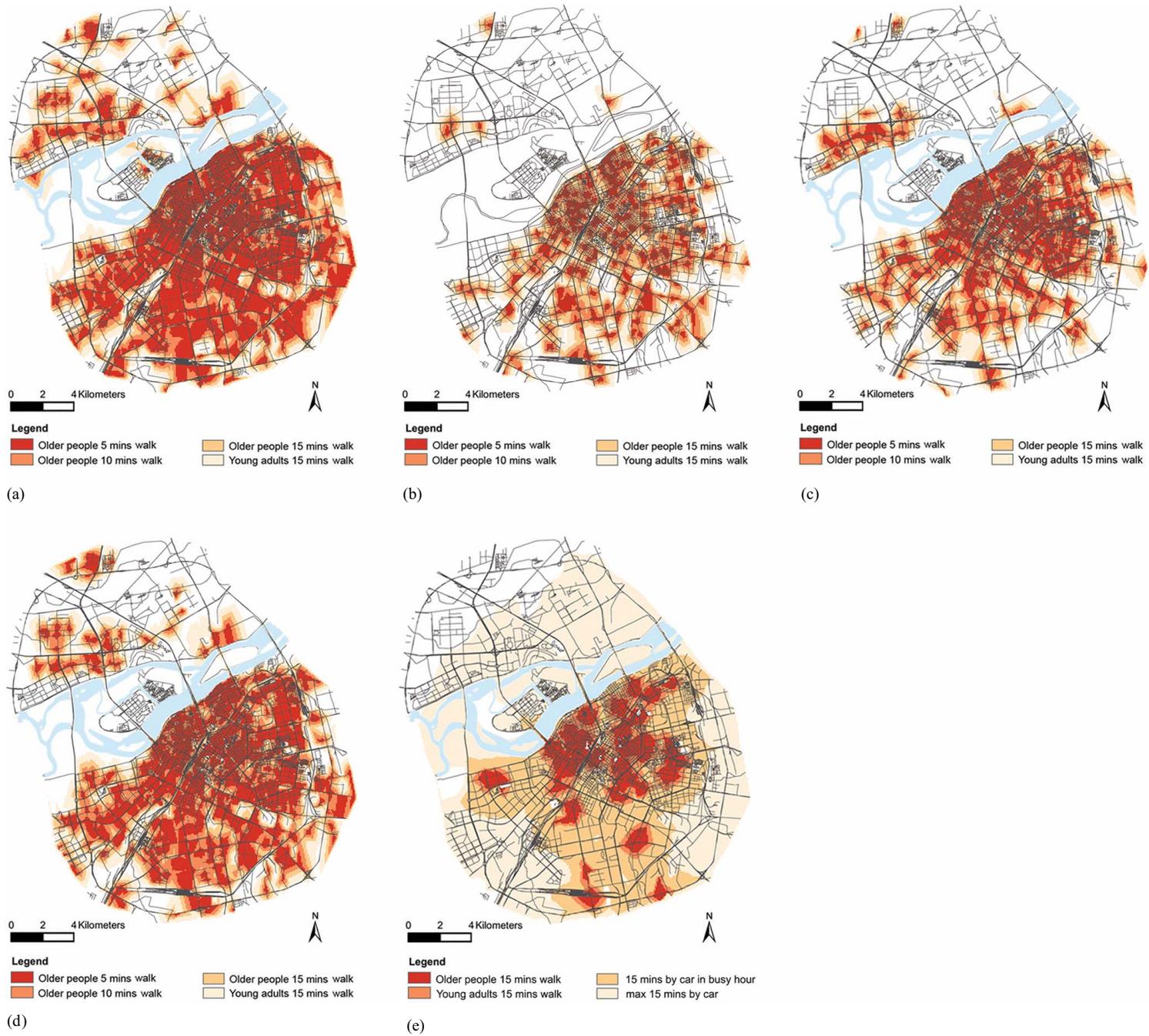


Fig. 5. Walkability and accessibility of current sufficient facilities: (a) general merchandise stores; (b) local grocery stores; (c) banks; (d) pharmacies; and (e) household agencies.

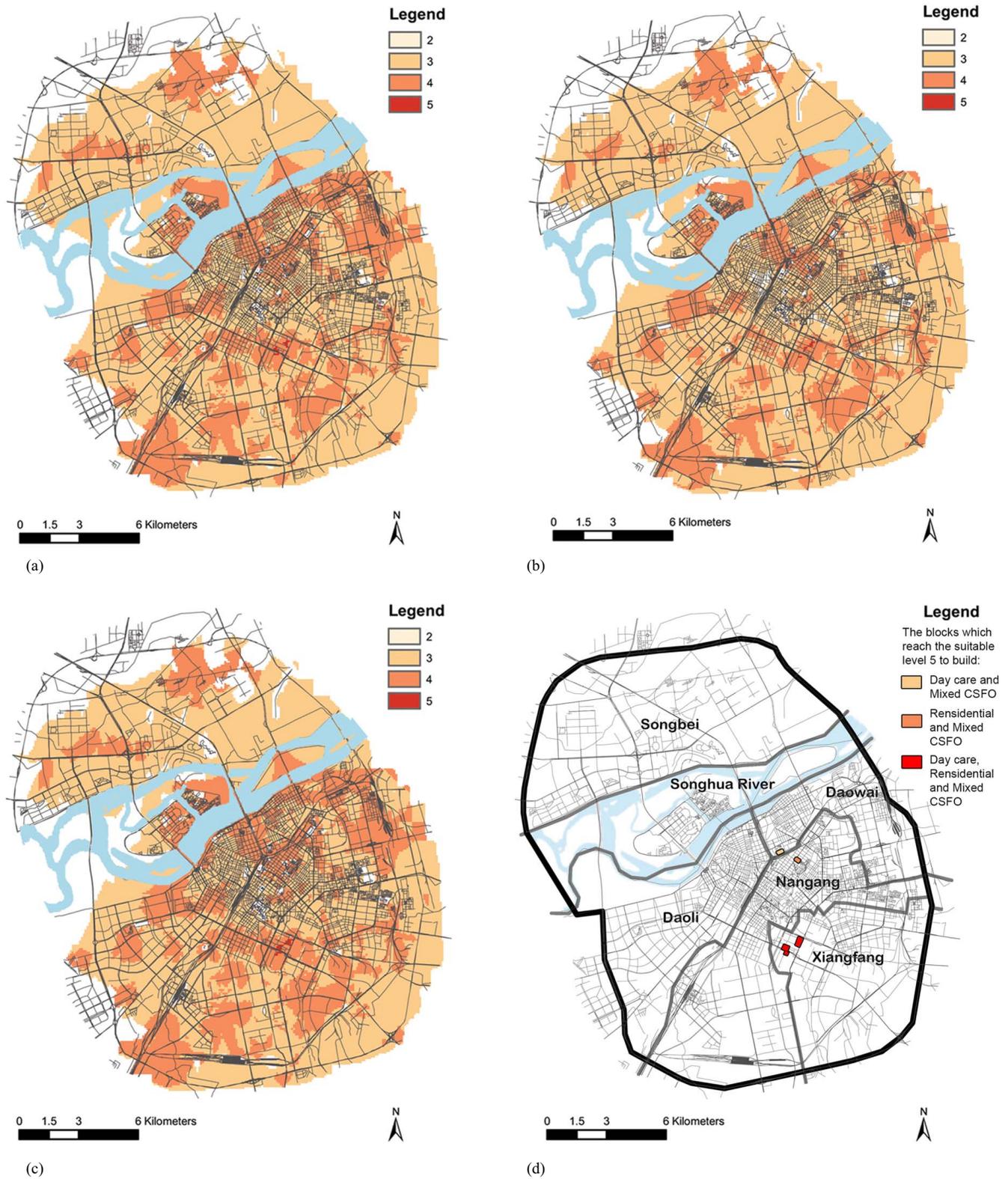


Fig. 6. Potential locations of new COSFs: (a) day-care CSFOs; (b) residential CSFOs; (c) mixed CSFOs; and (d) potential sites at the suitability level 5. All these three scenarios are testing results for new construction CSFOs.

Beijing, see Zhou et al. 2013). Another potential reason was the establishment of health-care facilities tended to lead to disputes between nurses and patients in China (Wang 2008). Supportive regulations for health-care agencies are thus needed.

Public Amenities as Part of Urban Planning

Public amenities such as community meal services, public restrooms, community health clinics, traditional Chinese medicine clinics, parks, and community centers are generally beyond walking distance

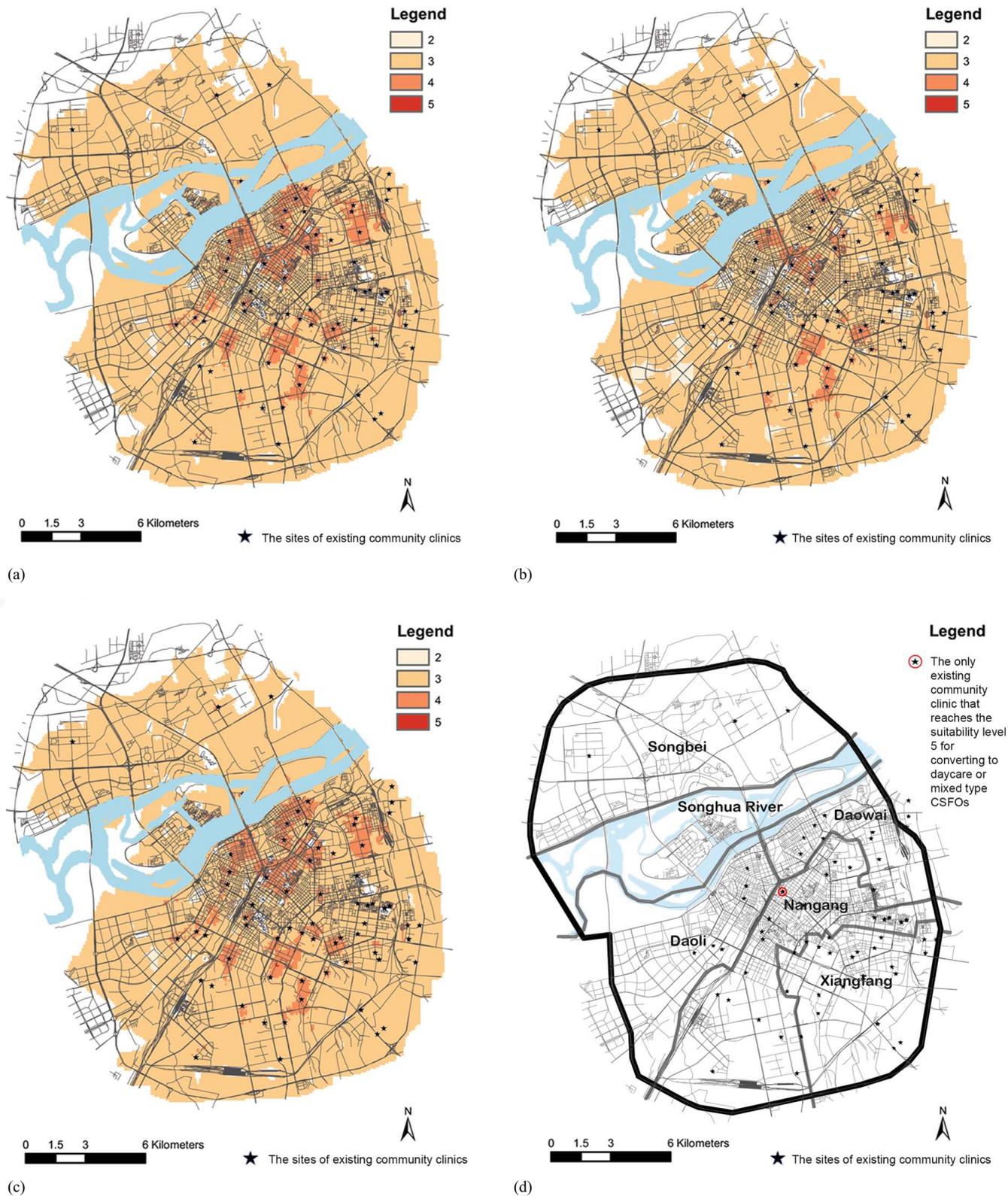


Fig. 7. Potential location of COSFs converted from community clinics: (a) day-care CSFOs; (b) residential CSFOs; (c) mixed CSFOs; and (d) potential sites at the suitability level 5. All these three scenarios are testing results for community clinic converted CSFOs.

from the homes of older adults within the majority of the study area. It is probable that this service gap occurs because Harbin’s municipal government distributed them based on an arbitrary service radius rather than walkability. The lack of parks may be due to urban

green space and urban renewal not becoming a norm in China until 30 years ago (Wolch et al. 2014; Zhang and Fang 2004).

The study findings call for nuanced analysis and planning of CSFOs in China while considering the differences between profit

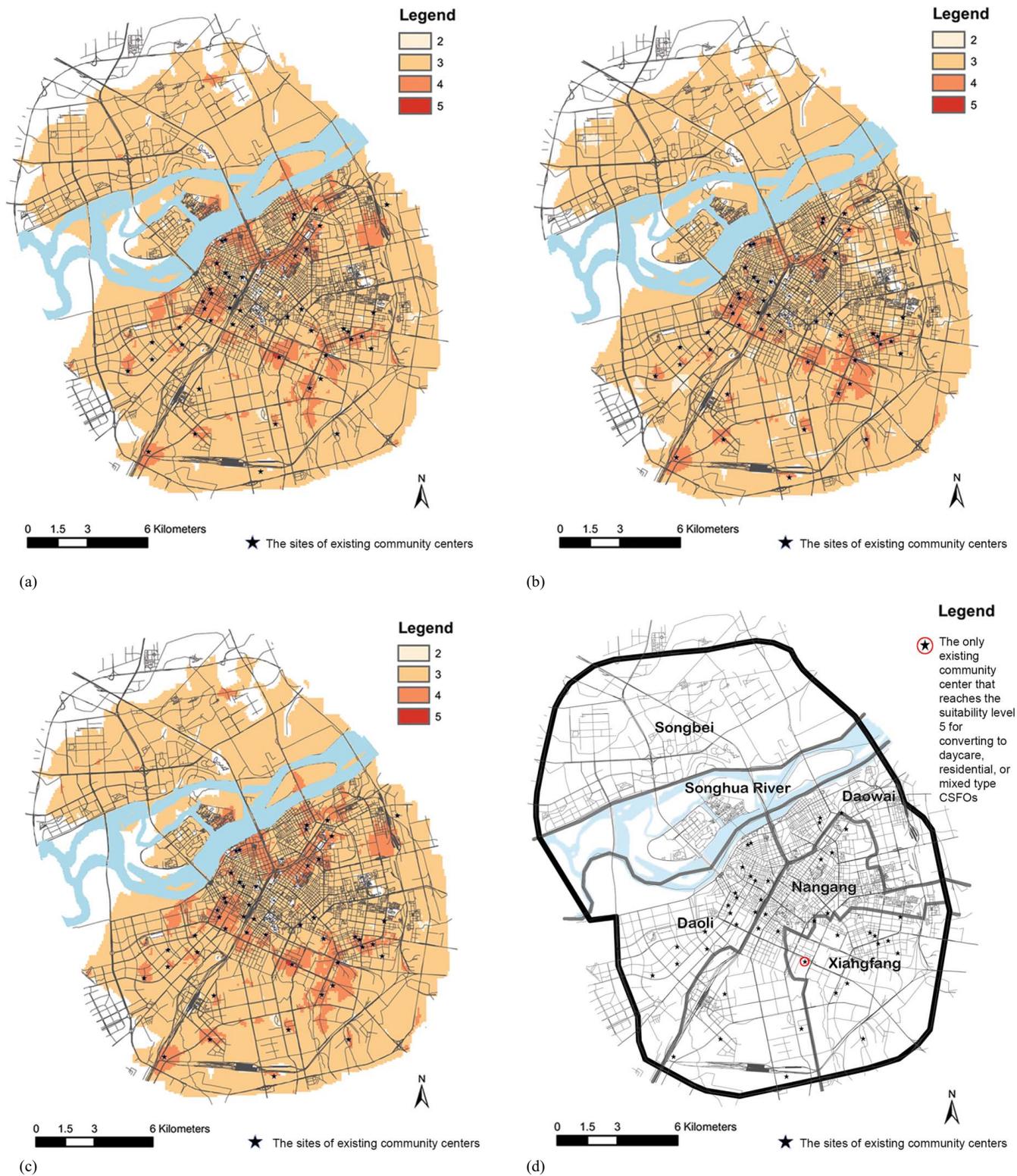


Fig. 8. Potential location of COSFs converted from community centers: (a) day-care CSFOs; (b) residential CSFOs; (c) mixed CSFOs; and (d) potential sites at the suitability level 5. All these three scenarios are testing results for community center converted CSFOs.

and nonprofit services and their need for governmental support; the importance of walkability over a service radius as a means to access services; and differences in the availability of public amenities in new versus old urban districts. While most up-to-date urban design theories that combine urban green space, livable communities, and

walkability (Wolch et al. 2014; Forsyth 2015; Ball 2012; Jun and Hur 2015) can offer many solutions to developing CSFOs throughout Harbin, China, the GIS-NEMA offers an effective means to identify ideal service networks as Harbin and other cities in China build age-friendly cities.

Conclusion

The current study proposes a methodological framework of identifying ideal service networks to facilitate aging in place based on the nested ecological model of aging in place and spatial analysis in GIS. By applying the method to the city of Harbin as a case study, the study identified the ideal distributions of three types of CSFOs in nine scenarios. The theoretically ground, data-driven approach also allows for developing architectural programming of new CSFOs based on the service mix already existing in a given neighborhood. Well-developed functional programming can provide more targeted services in each location. For example, a new CSFO can heavily invest in creating spaces for community socialization if the surrounding areas do not have existing community centers. In this sense, the proposed method provides a fertile ground for solving real-world problems in communities.

The study has several limitations. First, the study used an estimated number of older adults in each subdistrict because such data are available only at the city level in China. While the use of correlational analysis somewhat validates the assumption that services and population density correlate, the use of actual population numbers would have strengthened the study. Second, in developing alternative scenarios for converting existing services to new CSFOs, the study examined only two existing community facilities in addition to new construction: community centers and community clinics. While these two scenarios were chosen because they have been the two most widely adopted methods in China, other possibilities exist, such as converting community meal service facilities. Third, the study mainly focused on the spatial distribution of services facilities and the ideal locations for CSFOs, while leaving out many spatial issues at the micro level that critically influence experiences of older adults, such as the design of, and family members' attitudes toward, CSFO services.

Despite the limitations, the study offered an in-depth way to combine theories and research findings on aging in place on one hand and the use of GIS as an analytical tool on the other. This combination opens a door to fruitful discussion engaging public policy, urban planning, and architectural design in building an aging-friendly environment in Harbin and other cities in China. It is hoped that the demonstration in the current study inspires architects, urban planners, and policymakers to create aging-friendly cities in China and beyond.

Data Availability Statement

Some or all data, models, or codes generated or used during the study are available in a repository online in accordance with funder data retention policies (map.baidu.com). Some or all data, models, or code used during the study were provided by a third party. Direct requests for these materials may be made to the provider as indicated in the Acknowledgements.

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