Estimation of the quality of life in housing for the elderly based on a structural equation model

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Abstract
The housing environment is of utmost importance as people spend most of their time indoors; it is closely related to the occupant's quality of life (QOL) and health, especially among the elderly. This study evaluated the relationships among the architectural composition (AC), indoor environmental quality (IEQ), residential satisfaction (RS), and the QOL of those residing in housing for the elderly in Northeast China based on the results of a large-scale questionnaire and structural equation. The questionnaire was designed based on previous literature and included questions on the demographics, 11 items related to the AC, actual records, 19 measurable RS items, 6 measurable IEQ items, and 14 measurable aspects of QOL. The survey was conducted via face-to-face interviews, at 34 randomly selected homes for the elderly. In total, 1457 valid questionnaire responses were collected and checked using the reliability and validation tests. The results of the structural equation model indicated that the IEQ and RS have the greatest impact on the QOL, and act as intermediary variables, which indirectly affect the influence of the AC on the QOL. Therefore, the QOL of the elderly can be improved by enhancing the IEQ and RS. Overall, the results herein demonstrate that the structure equation model is valid, and the difference analysis indicates the differences in the evaluation results for buildings of different scales and structural characteristics. These results can make important contributions to the innovation of future housing for the elderly that can meet their needs and improve their QOL.
Keywords: Housing for the elderly · Indoor environment quality · Quality of life · Built environment · Residential aged care facilities · Structural equation model

1 Introduction

Population aging has become a global phenomenon in recent years. According to the WHO, soon the population of the elderly shall exceed that of children, which presents the challenge to meet the needs and preferences for the long-term care of the elderly, such as building infrastructure and housing for them (UN Department of Economic and Social Affairs, 2019). As of 2015, the proportion of elderly people throughout China was 10.5%.In comparison, the elderly population in the north-eastern provinces of Liaoning, Jilin, and Heilongjiang was 12.82%, 10.92%, and 11% of the total population, respectively (Maiet al., 2013). Therefore, the demand for elderly care is expected to increase over the next few years in Northeast China (Wu & Dang, 2013). As a result, the Chinese government is providing funds to the region and has pledged to provide more financial resources to develop a public regional cooperation framework adapted for the aging population

(Chen, 2009; Reynolds, 2014). With the growing number of elderly people and demand for suitable housing for the elderly in the last decade, the Chinese government has increased efforts to speed up its housing development. The current housing for the elderly market in China consists of elderly-adapted housing, apartments for the elderly, residential care facilities, and nursing homes, which can be either rented or bought and are specifically designed to meet the needs of the elderly. However, research on housing for the elderly in China is limited and the updated design standard titled, "Code for design of residential building for the aged" (MOHURD, 2018) primarily focuses on the minimal design standards and lacks details regarding their specific needs during housing development (Feng et al., 2012).

The built environment is a critical part of daily life and routine, and is closely related to the occupant's quality of life (QOL) and health, especially in the elderly as they tend to spend most of their time indoors owing to their declining physical functions and mobility (Andargie et al., 2019; Bamzar, 2019; Yu et al., 2017; Zhang et al., 2020). Many factors affect the residential environment, such as natural lighting, air quality, noise, and the green environment (Dzhambov et al., 2019; Shen et al., 2020). With the increase in the development of housing for the elderly, the architectural composition (AC) and indoor environmental quality (IEQ) of buildings have also changed, both of which can also affect the QOL for the elderly (Ibem & Aduwo, 2013; Onishi et al., 2010).

The IEQ is related to the indoor physical environment. Acoustic quality, lighting, thermal comfort, and indoor air quality can have an important impact on the safety and productivity of the building occupants (Altomonte & Schiavon, 2013; Vargas & Lawrence, 2017). Research has shown that the QOL of older adults in housing for the elderly can be accurately predicted from the IEQ, which is related to many aspects such as the building and occupant characteristics, physical location, and different heating and cooling systems(Gou et al., 2012; Mendes et al., 2015; Recek et al., 2019). During the winter, Northeast China is cold and dry, and people have higher requirements for comfortable indoor temperatures, especially the elderly (Collins et al., 1995; Rockwood et al., 2005). However, because of old heating equipment and aged housing materials, it can be difficult to meet the temperature needs of the elderly (Tsuzuki et al., 2015; Yin & Liu, 2008). Currently, local governments in Northeast China are taking efforts to resolve this problem by using exterior wall insulation, floor heating, and improved residential heating designs (Yu et al., 2008).In addition, air quality has an important impact on the health and life of the elderly (Tonget al., 2020; Xu et al., 2016). Therefore, it is very important to improve the elderly's housing environment by using specialised indoor systems that can optimise their physical and mental comfort.

Another factor affecting the QOL of the elderly is the residential satisfaction (RS),which largely depends on their subjective feelings about factors such as their indoor environment, evaluation of surrounding shops and services, familiarity with elderly housing, and satisfaction with housing and neighbourhood relations. In addition, the elderly have a higher degree of need for retention, accessibility, and identifiability, and places with less restraint meet certain needs better (Zhang & Qiu, 2020). In view of these factors, improvements in housing for the elderly is of great significance and more research is needed regarding the perspectives of the elderly on housing needs such as the facilities, management, and service quality which directly affects them (Leung et al., 2017; Zarghami et al., 2019).

Overall, the literature supports the idea that improving the housing environment has a great effect on QOL, however research on the living environment of the elderly and their QOL remains limited (Gou et al., 2018). Considering multi-level comprehensive factors, such as the AC, RS, and IEQ, a comprehensive evaluation of the QOL of the elderly with respect to their housing situation can be performed. Previous studies have used simple linear regression, probity regression, and logistic regression, however, these methods only study the influence of independent variables on dependent variables and do not consider the intrinsic correlation among the independent variables (WHO, 1996).

The purpose of this study was to establish a structural equation model that can be used to study the interrelationships among the AC, IEQ, and RS, as well as the influence of each variable on the overall QOL of the elderly, to analyse how these are related to their housing environment (Ren & Folmer, 2017). We conducted surveys among the participating elderly and analysed their responses to evaluate the following research questions: (1) what is the correlation between the facility size and the evaluation values of AC, RS, IEQ, and QOL? And (2) how are the AC, RS, and IEQ related to the QOL and each other? The results of this research can contribute to the innovation of future policies on housing for the elderly, and of housing design that meets their needs and improves their QOL.

2 Literature review

As the elderly are confronted with the gradual decline in their physical functions and certain social changes, they need flexible strategies and a constantly changing and evolving environment to adequately cope with issues related to aging. Related research has mainly concentrated on the impact of the housing environment on the health and QOL of the elderly and considers it a crucial factor in healthy aging (Feng et al., 2018; Garre-Olmo et al., 2012; Lai et al., 2021; Ren et al., 2019). Functional differences exist between housing for the elderly and normal residential buildings, such as group activities to encourage interaction among the elderly, strict security measures, access to different types of care, and more control over the IEQ related to light, noise and temperature. A previous review has pointed out that different ACs that enable exercise, interaction, and contain green environments, can not only affect the physical health of the occupants, but also their mental health, social relations, and the living environment (Zhou et al., 2017; Garin et al., 2014). Leung et al. (2019) used questionnaires to evaluate the correlation between the AC and QOL of the elderly. Their results indicated that furniture and fixtures, distance between rooms, and handrails significantly affected the overall QOL of the participating elderly. Another study has shown that interior housing conditions, such as lighting, temperature, and stairs have a bigger impact on the QOL of the elderly compared to exterior conditions like green zones and rest areas (Lu, 2020). An appropriately sized space can provide a suitable place for communication and prevent loneliness in the elderly, which is a problem as some elderly people feel depressed and their self-esteem decreases following retirement or physical disability (Gou et al., 2018). The concepts of QOL, well-being, and satisfaction are very much related, while RS could be considered as an indicator of subjective QOL (Aragonés et al., 2017). One of the first studies that evaluated the factors that contribute to the RS was conducted by Francescato et al. (1974). They conducted questionnaires and interviews and concluded that the following aspects were related: the physical characteristics of the dwelling, residents' perceptions and behaviours, demographic characteristics, perceptions and regulations as stipulated by the management, and relationships between the dwellings and the community in the neighbourhood. Experts realized early on that the RS consists of multi-dimensional aspects. More recent literature defined RS as the fulfilment of individual residential criteria (home, district, and community) in relation to the needs, expectations, and objectives of the residents (Fernández-Portero et al., 2017). This relationship between people and the environment is connected to many objective (i.e., physical features of the dwelling, facilities, and socio-demographic characteristics) and subjective parameters (cognitive and emotional factors) and has led to a search for indicators to define this relation using survey data (Fernández-Carro, 2015; Perez et al., 2001). RS has been the most widely used parameter for measuring the subjective adequacy of the housing environment, as it evaluates measures that include feelings of emotion and responses in relation to the socio-physical living environment (Aragonés et al., 2017; Fernández-Carro et al., 2015).

Numerous studies have shown that IEQ is an important part of the indoor environment that has a great influence on the comfort of building occupants and enhances their QOL (Vargas & Lawrence, 2017; Altomonte & Schiavon, 2013; Garre-Olmo et al., 2012; Frontczak & Wargocki, 2011). The IEQ is related to the acoustic, lighting, and thermal environments, and the indoor air quality (Feng et al., 2018; Garre-Olmo et al., 2012; Frontczak & Wargocki, 2011). Previous research has shown that the elderly usually demand higher environmental temperatures, which could be attributed to their biological decline, for example, their weakened ability to regulate their body temperature, and lesser physical activity resulting in a lower metabolic rate (Hwang & Chen, 2010;). Similar results were also reported by Mendes et al. (2015); less thermal comfort was correlated with a poorer selfreported health and QOL.

One of the most accepted definitions of QOL is proposed by the WHO QOL Group as follows: "individuals' perception of their position in life in the context of the culture and value system in which they live and in relation to their goals, expectations, standards, and concerns" (WHOQOL Group, 1995). The QOL of elderly people is studied from the standpoint of various disciplines (economics, psychology, biology, or medicine) and encompasses many dimensions. Its relevance has been scientifically proven and it has a great influence on the design of social policies for well-being. QOL is a dynamic concept which differs among age, individuals, and cultures, and with regards to elderly people, it is primarily related to their health or social relationships (Elosua, 2011).

Incorporating all the above, the innovation of future housing for the elderly that can meet their needs and improve their QOL includes three aspects: IEQ, perceptive comfort (RS), and functionality of space (AC). These three aspects interact closely with one another and influence both physical and psychological states.

To explore the correlation between the determinants we used a mixed-method approach. Based on the comprehensive literature review, we developed a questionnaire and structural equation model to analyse the results along with the objective data.

3 Methods

In this study interviews were conducted with elderly living in different types of housing (for the elderly). For the interviews, a questionnaire was designed based on the literature, where in the contents included personal information of residents, building data, IEQ of the elderly, and a QOL evaluation. A structural equation was developed to study the relationships among the AC, RS, IEQ, and QOL of the elderly. SPSS and AMOS were used to analyse the results of the questionnaire as well as the actual test results.

3.1 Collection of the sampling data

The study area involved three ordinary provinces in Northeast China: Heilongjiang, Jilin, and Liaoning. In these regions, both government financial allocations and social capital investments provide support for the endowment of resources (Pan & Sun, 2004). The fiscal expenditures of China on social elderly care services are mainly focused on the following two major sectors; I: the build-up of social welfare facilities and institutions, and II: the development of housing for the elderly.

As the major targets of this research study, the following four cities in the Northeast were singled out: Harbin (provincial capital of the Heilongjiang province, Changchun (provincial capital of Jilin province), Shenyang (provincial capital of Liaoning province), and Dalian (a coastal city in the developed economy region of Liaoning province) (Fig. 1).

As stated in GB 50,176–2016, which is the thermal design code for civil buildings, these cities are in cold regions and have long winters with cold weather conditions. For instance, the mean and maximum temperatures of July in Harbin are 22 °C and 38 °C, respectively, but during the winter, the mean temperature of January varies from − 15 to − 30 °C, with the minimum as low as − 37.7 °C. The winter is long with cold and dry air, and snowstorms and blizzards occur occasionally (Sun, 2013).

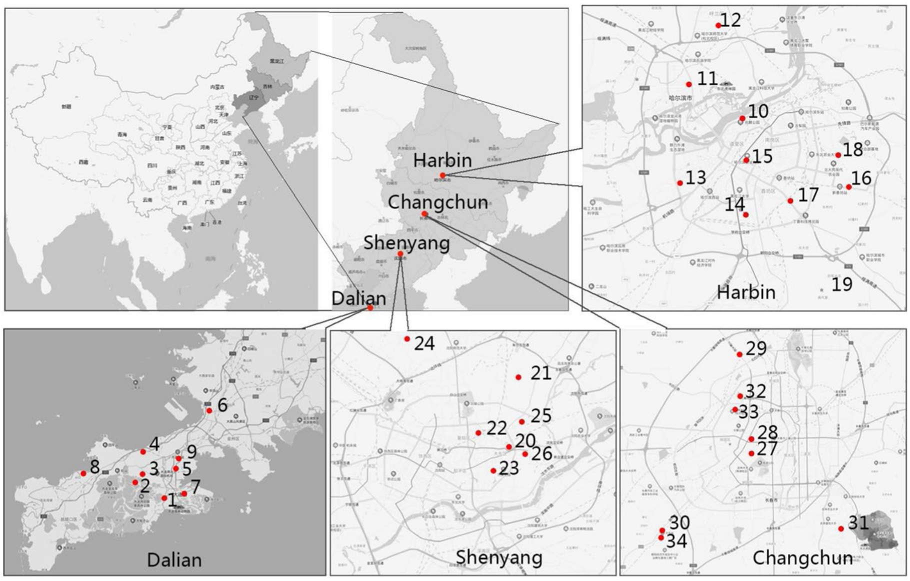


Fig. 1 Distribution analysis of housing for the elderly

According to the summarised registration information regarding housing for the elderly in these cities, the number of locations of the housing for the elderly distributed among these cities is 374 (Changchun), 169 (Shenyang), 261 (Harbin), and 476 (Dalian). For the sampling approach herein, 34 housing for the elderly of different types (Table 1) were randomly selected and surveys were performed after researchers were granted access to them.

The occupants are provided with boarding, three meals per day, activity spaces, basic medical provisions, and a laundry service. Subject to the scale and construction features of properties (retrofitted or not), the selected housing for the elderly was classified under different categories. Considering the seasonal transition influence on the occupancy rate and the perception of the facilities, surveys were conducted for divided seasonal units (Yanget al., 2016). Table 2 summarises the detailed information regarding the surveyed locations. Further, to adhere to the GB 50,867–2013 (Chang et al., 2014): design code for housing for the elderly, further subdivision was carried out as follows:

- Small: Beds equal or less than 150
- Medium: Beds between 151 to 300
- Large: Beds between 301 to 500
- Super-large: Beds greater than 500

As stipulated in the newest design standard for housing for the elderly in China, i.e., JGJ450-2018, single bedrooms should occupy > 10 m^2 and double bedrooms > 16 m^2 witha minimal ceiling height of 2.4 m. In addition, rest areas should occupy > 4 m^2 per resident, restaurant seating areas > 2.5 m^2 per seat, leisure activity and exercise areas > 2 m^2 per resident, and the medical clinic > 10 m^2 (MOHURD, 2018).

Consequently, housing of different scales for the elderly were singled out as objects of the surveys.

3.2 Questionnaire

An exploratory mixed approach (Creswell, 2013) was applied in this study as described by Greene et al. (1989) for mixed-method evaluation designs; the purpose of using this approach was to consider categorised classifications.

First, at the qualitative stage of the research, RS/dissatisfaction and factors contributing to the QOL were explored. The basic framework and dependent variables were developed by referencing the literature.

The second step of this research involved personal interviews by applying a semi-structured interviewing approach; 80 face-to-face interviews between occupants and researchers were conducted at 10 different homes for the elderly located in the targeted cities to identify the elements that could contribute to the QOL of the elderly residents. The interviews yielded insightful details regarding the personal views of the occupants.

Each interview started with the question: "Why did you select this housing for the elderly to live in, and do you intend to move to another one?" The subsequent question was: "For what reasons are you considering moving out or staying?" These questions helped to identify the problematic issues that existed in their homes (Riazi & Emami, 2018). Moreover, the occupants were encouraged to elaborate on their daily lives, including sharing their activity arrangements, behaviour traits, mood alterations, feelings, and thoughts. Each interview lasted 30–45 min, and all dialogues were recorded in a digital format. During the interview, under the guidance of researchers, participants spoke about their feelings and thoughts regarding the RS, IEQ, and QOL.

Next, we evaluated the data acquired from the interviews. The interviews gained us insight into the experiences and views of the participants. After completing the data analysis for all 80 interviews, the key influencing factors were identified for potential improvement within the designated framework which resulted in a final questionnaire. Given the functional differences between the housing for the elderly and the normal residential buildings, as well as the specified living demands of the elderly, the questionnaire design surrounding the RS and QOL in the housing for the elderly varied and was different from that of other residential buildings.

The main issues for the IEQ evaluation included, the indoor acoustic environment, daylighting, temperature, humidity, air ventilation, and air quality. Prior to the interpretation of the results (Riazi & Emami, 2018), the evaluation of RS was composed of the following six aspects: property management, characteristics of the housing for the elderly, ambient conditions, room features, types of auxiliary service facilities, and locations of auxiliary service facilities, wherein each aspect was covered by 2–5 questions. The AC was covered by three aspects concerning design and neighbourhood and consisted of 11 questions. For the QOL evaluation, four factors were considered and the overall QOL was appraised with a modification in accordance with the WHO QOL Brief Scale.

A 7-point Likert scale (Associate et al., 2017) (ranging from 1: unsatisfied to 7: very satisfied) was applied to measure the feedback responses of the participants to the questionnaires with measurable items concerning AC (11 items), RS (19 items), IEQ (6 items), and QOL (14 items).

Table 1 Details of the chosen housing for the elderly

Name	City	Building area	Bed	Construction date	Rebuild	Ownership	Price range
NS care home	Dalian	4500	130	2008	No	Public	1000–2000
Red flag welfare center	Dalian	8800	260	2004	Yes	Public	1999–3199
WG nursing home	Dalian	9200	300	2006	No	Private	660–1336
YHZ apartment	Dalian	9000	360	2012	No	Private	2600–5800
JJS retirement center	Dalian	10,000	300	2016	No	Private	2500–3200
JZ social welfare home	Dalian	29,000	750	1999	No	Public	700–900
SS nursing home	Dalian	9269	100	2011	No	Private	6000–10,000
Longevity apartment	Dalian	4200	168	2009	Yes	Private	1600–3000
Happiness care home	Dalian	2700	60	2010	Yes	Public	700–2300
HIT apartment	Harbin	6050	150	2003	Yes	Public	500–1000
RF apartment	Harbin	110,000	2000	2014	No	Private	1800–4500
AK social welfare home	Harbin	66,000	1500	2003	No	Public	1800–3500
KFY nursing home	Harbin	2800	135	2015	No	Private	1580–2680
The first social welfare home	Harbin	15,200	550	1998	No	Public	500–1000
HIT activitycenter	Harbin	18,000	450	2008	No	Public	1200–2500
CHDH apartment	Harbin	8000	500	2017	No	Private	800–4000
XF apartment	Harbin	3000	150	2018	No	Private	2000–6000
XS apartment	Harbin	18,000	292	2016	No	Private	4000–7000
KLG apartment	Harbin	8000	200	2015	No	Private	1300–1500
DD elderly service center	Shenyang	10,000	300	2002	No	Public	500–1000
AD apartment	Shenyang	11,000	250	2012	No	Public	1800–3000
HG social welfare home	Shenyang	9000	140	2004	Yes	Public	360–760
SH elderly service center	Shenyang	4600	120	2001	Yes	Public	540–800
CSC retirement center	Shenyang	130,000	3500	2014	No	Private	2500–5800
BY care center	Shenyang	5000	180	2009	Yes	Private	1500–2600

Table 1 (continued)

Name	City	Building area	Bed	Construction date	Rebuild	Ownership	Price range
Dawn nursing home	Shenyang	6000	265	2004	Yes	Private	700–1500
QQY apartment	Changchun	7677	200	2016	Yes	Private	6000–11,000
QXY retirement center	Changchun	1600	60	2014	Yes	Private	3000–6000
XH nursing home	Changchun	6000	250	2013	Yes	Private	800–2000
YL rehabilitation center	Changchun	54,500	500	2015	No	Public	1980–4800
JYYK nursing home	Changchun	28,000	800	2017	No	Private	2500–6000
Sunshine home nursing home	Changchun	4900	290	2019	Yes	Private	2500–9500
Green park care home	Changchun	1500	110	1997	No	Public	800–1500
Changchun social welfare institute	Changchun	15,000	300	2003	No	Public	1000–3000

Table 2 Items on the questionnaire

AC			RS						IEQ (F10)	QoL				
F1-Planning policy	F2-Design principles	F3-Interaction with neighbours	F4-Management of estates	F5-Dwelling unit features	F6-Neighbourhood environment	F7—housing unit characteristics	F8—type and location of resident	F9—Dwelling unit supports services		Q1-Overall QOL	Q2-Physical health	Q3-Psychological health	Q4-social relationships	Q5-Living environment
F11 Commuting cost	F21 Benches in public open spaces for elders	F31 Neighbours' cooperation in payment of monthly charges and cleaning	F41 Management and maintenance of facilities	F51 Sizes of living and dining spaces	F61 Recreation/sporting facilities	F71 Building materials used in the construction of houses	F81 Location of residence in the estate	F91 Water supply and sanitary services	F101 Acoustic environment	How would you rate your quality of life?	How satisfied are you with your sleep?	How much do you enjoy life?	How satisfied are you with your personal relationships?	How satisfied are you with the conditions of your living place?
F12 Distance to urban facilities	F22 Lighting of public areas	F32 Conflict between neighbours	F42 Cleanliness of the housing estate	F52 Sizes of bedrooms in the house	F62 Prices of goods and services in the housing estate	F72 Privacy in the residence	F82 Public infrastructure and urban services	F92 Electrical services	F102 Lighting environment	How would you rate your overall health?	Do you have enough energy for everyday life?	How often do you have negative feelings, such as blue mood, despair, anxiety, depression?	How satisfied are you with the support you get from your friends?	How safe do you feel in your daily life?

Table 2 (continued)

AC			RS						IEQ (F10)	QoL				
F1-Planning policy	F2-Design principles	F3-Interaction with neighbours	F4-Management of estates	F5-Dwelling unit features	F6-Neighbourhood environment	F7—housing unit characteristics	F8—type and location of resident	F9—Dwelling unit supports services		Q1-Overall QOL	Q2-Physical health	Q3-Psychological health	Q4-social relationships	Q5-Living environment
F13 Quality of constructions and need for repair	F23 Security in stairs and corridors	F33 Profligate tenants	F43 Security of life and property in the housing estate	F53 Sizes of cooking and storage spaces	F63 Communal activities in the housing estates	F73 Cost of housing			F103 humidity			How satisfied are you with yourself?		Have you enough money to meet your needs?
	F24 Accessibility facilities		F44 Rules and regulations within the housing estate	F54 Design of baths and toilet facilities		F74 External appearance of the residence			F104 temperature			Are you able to accept your bodily appearance?		How satisfied are you with your access to health services?
	F25 Road lights								F105 Ventilation					
									F106 air quality					

Additionally, personal information of the participants in different housing for the elderly locations were collected (Table 2).

The acquired responses for the measurable items were quantified and then grouped based on their quantified value.

3.3 Participants

A total of 34 homes for the elderly in Northeast China were selected stochastically for this research. The following inclusion criteria were applied: (1) aged 55 or older, (2) residence duration of at least one month, (3) able to communicate, and (4) voluntarily participating in this study. The residents of housing for the elderly did not require a high level of medical supervision and nursing care and agreed on living there. In consideration of mobility limitations and physical decline of the elderly, the questionnaire was implemented via personal interviews in a one-on-one question and answer (Q&A) mode. Generally, the interviewer took 5–10 min to finish each questionnaire survey (Altomonte & Schiavon, 2013; Guo, 2013). This approach was applied to both prevent misunderstanding of the contents of the questionnaire due to possible declined reading and writing abilities of the participants as well as to improve the return rate and validity of the responses. Among the total 1663 collected questionnaires, 1457 of them were valid, wherein 27.6% of the validated questionnaires (402) were conducted in winter, 26.8% (390 questionnaires) in summer, and 45.6% (665 questionnaires) during a seasonal transition (Table 3).

The participants involved in the questionnaire surveys were selected stochastically from the occupants aged 55 years and older. The findings of previous research have indicated that demographic differences, such as age differences, are an influencing factor for subjective assessments (Alkabashi & Yörükoğlu, 2019). In order to minimise the negative impacts or contingent errors due to the age-related influencing factor on the questionnaire results used herein, a balanced demographic structure of participants was developed. Furthermore, a previous study remarked that specific perceptions are subject to alterations among opposite genders (Alkabashi & Yörükoğlu, 2019); thus, in this research, consideration was given to balance the gender among the participants as well. Allowing for the comprehensive consideration of all aspects of income, civil state, education, age, and gender, the sampling size for each aspect was set at a minimum of 30 answers (Yin & Lin, 2008). Note that female occupants outnumbered male occupants in all the targeted homes for the elderly. The age of the participants varied in the range of 55–95, and the female/male ratio was set as 1.07:1 (women: 753, men: 704) to ensure a balanced sampling ratio. Table 4 summarises the classification information related to the social and behavioural characteristics of the participants.

Table 3 Survey site classifications based on their city location, testing season, size, and resident satisfaction levels

	Classification	Number	Percentage (%)
City	Changchun	346	23.7
	Harbin	485	33.3
	Shenyang	420	28.9
	Dalian	206	14.1
Season	Winter	402	27.6
	Sumer	390	26.8
	Transition	665	45.6
Scale	Small	352	24.2

	Medium	280	19.2
	Large	625	42.9
	Super-large	200	13.7
Satisfaction level	1. Very dissatisfied	152	10.4
	2. Dissatisfied	150	10.3
	3. Slightly dissatisfied	174	11.9
	4. Neither satisfied nor dissatisfied	566	38.8
	5. Slightly satisfied	75	5.2
	6. Satisfied	176	12.1
	7. Very satisfied	164	11.3

3.4 Data analysis

SPSS 22.0 and AMOS 22.0 were used to analyse the sampling data acquired from the questionnaires. To estimate the reliability and consistency of the questionnaires and validate their development, testing of the Cronbach's alpha coefficient and a confirmatory factor analysis were conducted.

To evaluate the quality of the housing for the elderly, a difference analysis was performed to examine the differences caused by varied scales, differentiated architectural features (retrofitting or not), and alternations in seasons. Meanwhile, an analysis was performed to explore the relevance of different variables. Then, AMOS was used to construct a structural equation model in accordance with the assumed hypotheses and the conceptual model, wherein the hidden variables were reflected by the observable variables. The correlations among the hidden variables were examined by assessing the fitting degree between the actual data and the structural equation model, and thereafter, the theoretical hypotheses were substantiated.

Table 4 Social and behavioural characteristics of the survey participants

Social characteristics	Classification	Number	Percentage (%)
Gender	Male	704	48.3
	Female	753	51.7
Age (years)	55–60	271	18.6
	61–70	424	29.1
	71–80	359	24.6
	81–90	323	22.2
	91–95	80	5.5
Education level	No schooling	248	17
	Primary school	350	24
	Junior school	271	18.6
	Senior school	274	18.8
	College	284	19.5
	Graduate or higher	30	2.1
Income (RMB)	≤1000	197	13.5
	1001–2000	264	18.1
	2001–3000	278	19.1
	3001–4000	306	21

	4001–5000	241	16.5
	≥5001	171	11.8
Marital status	Unmarried	39	2.7
	Married	801	55
	Divorce	341	23.4
	Widowed	276	18.9
Duration of residency (months)	1–6 months	462	31.7
	6 months to 1 year	239	16.4
	1–3 years	222	18.3
	3–5 years	272	18.7
	Over 5 years	173	14.9

4 Results

4.1 Reliability and validity

A survey method was adopted to assess the living environment of housing for the elderly in Northeast China in regard to the following three factors: AC, IEQ, and RS, and their relation to the QOL. An exploratory factor analysis was performed on 50 projects, and the four variables listed in Table 2 were obtained as the principal components.

Cronbach's alpha (α) is often used to estimate reliability. Scholars generally believe that if the Cronbach's alpha is greater than 0.9, the internal consistency of the variable is excellent, if $0.9 > \alpha \geqslant 0.7$, the internal consistency is acceptable, and if $0.7 > \alpha \geqslant 0.5$, the internal consistency is questionable and poor (George & Mallery, 2003). According to Table 5, all the variables in this study can be considered as reliable.

Construct validity refers to the correspondence degree between the actual value and the predicted value of the measurement results. Notably, a factor analysis is the commonly used method for measuring construct validity. The results in Table 6 show that the data were eligible for factor analysis. Thus, we could extract three main factors (F1–F3) from 11 items in the AC, six main factors (F4–F9) from 19 items of the RS, and five main factors (Q1–Q5) from the 14 items of the QOL, while all six items in the IEQ were determined as primary influencing factors. The cumulative variance contribution rate of the extracted factors exceeded 50% and the eigenvalue was greater than 1, indicating that the factor analysis results were reliable for calculating the AC, RS, IEQ, and QOL. The Cronbach's alpha of each factor was greater than 0.5, the factor loading of each item was greater than 0.7 or 0.9, and there was no cross-loading between them, indicating that these variables possess good or excellent structural validity.

4.2 Facility size analysis

4.2.1 Difference analysis of facility size

The P-values in Table 7 showed significant differences between the quality evaluation values of the housing for the elderly at different scales. The difference between the small and medium scales was more significant than that at the large scale for AC. The difference between the medium and large scale was more significant than that at the small and mega-scales for RS, and for the IEQ and QOL, the differences between the medium scales were more significant than the others. Overall, the evaluation values for almost all variables were the highest among the residents of medium sized facilities, only for the RS, large facilities had a slightly higher evaluation value.

Although large-scale housing for the elderly has advanced facilities, the architectural plans are complex, which makes it difficult for the elderly to familiarise themselves with the buildings. Some interviewed elderly said that the large rooms are far from each other and lack a sense of warmth. In general, the consensus expressed that mediumsized housing for the elderly feel the best because they have enough personal space, the facilities are not too confusing, and the activity area is moderate.

Table 5 Results of the reliability test

Variables	Cronbach's alpha (α)	Number of items
AC	0.911	11
IEQ	0.939	6
RS	0.799	19
QoL	0.789	14

Table 6 Construct validity

		Factor loading						Cronbach's
Constructs	Items	1	2	3	4	5	6	Alpha
F1	F11		0.773					0.902
	F12		0.814					0.905
	F13		0.800					0.905
F2	F21	0.736						0.903
	F22	0.762						0.899
	F23	0.813						0.898
	F24	0.778						0.902
	F25	0.765						0.908
F3	F31			0.778				0.902
	F32			0.872				0.905
	F33			0.82				0.905
	Eigenvalue	5.861	1.335	1.008				
	% of Variance	53.282%	12.137%	9.164%				
	Cum%	53.282%	65.418%	74.582%				
	KMO		0.889					
	Bartlett test		10317.371					
	Sig.		0.000					
F4	F41	0.931						0.787
	F42	0.852						0.788
	F43	0.877						0.790
	F44	0.798						0.790
F5	F51		0.845					0.788
	F52		0.828					0.791
	F53		0.853					0.788
	F54		0.824					0.794
F6	F61				0.902			0.792
	F62				0.835			0.790
	F63				0.777			0.794
F7	F71			0.819				0.789

	F72			0.749				0.788
	F73			0.806				0.788
	F74			0.793				0.788
F8	F81						0.823	0.789
	F82						0.867	0.795
F9	F91					0.852		0.792
	F92					0.855		0.793
	Eigenvalue	4.16	3.047	2.063	1.98	1.318	1.224	
	% of Variance	21.896%	16.034%	10.86%	10.42%	6.936%	6.44%	
	Cum%	21.896%	37.931%	48.791%	59.21%	66.146%	72.586%	
	KMO	0.794						
	Bartlett test	11824.51						
	Sig.	0.000						
F10	F101	0.192						0.925
	F102	0.183						0.932
	F103	0.189						0.928
	F104	0.199						0.921
	F105	0.18						0.934
	F106	0.198						0.922
	Eigenvalue	4.606						
	% of Variance	76.758%						
	Cum%	76.758%						
	KMO	0.897						
	Bartlett test	7856.243						
	Sig.	0.000						
Q1	Q11			0.827				0.765
	Q12			0.865				0.778
Q2	Q21					0.912		0.786
	Q22					0.757		0.773
Q3	Q31		0.865					0.768
	Q32		0.750					0.766
	Q33		0.785					0.784
	Q34		0.802					0.782
Q4	Q41				0.834			0.784
	Q42				0.871			0.789
Q5	Q51	0.745						0.761
	Q52	0.845						0.778
	Q53	0.808						0.778
	Q54	0.827						0.780
	Eigenvalue	3.885	2.318	1.722	1.317	1.035		
	% of Variance	27.751%	16.558%	12.303%	9.408%	7.394%		
	Cum%	27.751%	44.309%	56.612%	66.02%	73.414%		
	KMO	0.782						
	Bartlett test	7484.62						
	Sig.	0.000						

Note: KMO = Kaiser-Meyer-Olkin; Sig = Significance

Table 7 Difference analysis of each variable with different sizes

	Small	Medium	Large	Mega	F	P	η_p^2
AC	4.790	4.954	4.231	4.107	35.254	0.000	0.065
IEQ	4.340	4.796	4.016	4.544	22.744	0.000	0.025
RS	4.196	4.310	4.330	4.045	7.651	0.000	0.038
QOL	4.219	4.509	4.230	4.322	7.102	0.000	0.017

4.2.2 Questionnaire results and facility size

Figure 2 shows the evaluation results for 15 factors in regard to the different sizes of housing. For the AC, negative evaluations by the elderly were mainly related to large- and mega-sized housing for the elderly.

In terms of housing management, small-sized housing for the elderly had the highest satisfaction because the smaller number was conducive to the management and care of the elderly by the nursing staff. However, the weakness of small-sized housing for the elderly includes relatively simple equipment, small personal spaces, poor privacy, and low-grade decorations. The satisfaction regarding small-sized housing for the elderly was only 4.1 on the housing unit characteristics factor, which was lower than that of other scales. Although the hardware facilities are gradually improving, we found that in addition to the higher management satisfaction of small-sized housing for the elderly and the management level of large-sized ones, the management satisfaction and management level of medium- and mega-sized housing for the elderly was lower.

4.3 Correlation analysis between variables

4.3.1 Correlation coefficients

According to Table 8, AC was positively correlated with RS, IEQ, and QOL, and the correlation coefficients were all greater than 0.5 ($P < 0.01$), which suggests that the correlations were relatively strong. The correlation coefficient between IEQ and RS was significantly negative ($P < 0.01$), whereas the correlation coefficient between QOL and RS was significantly positive ($P < 0.01$). Further, there was a positive correlation between the IEQ and QOL.

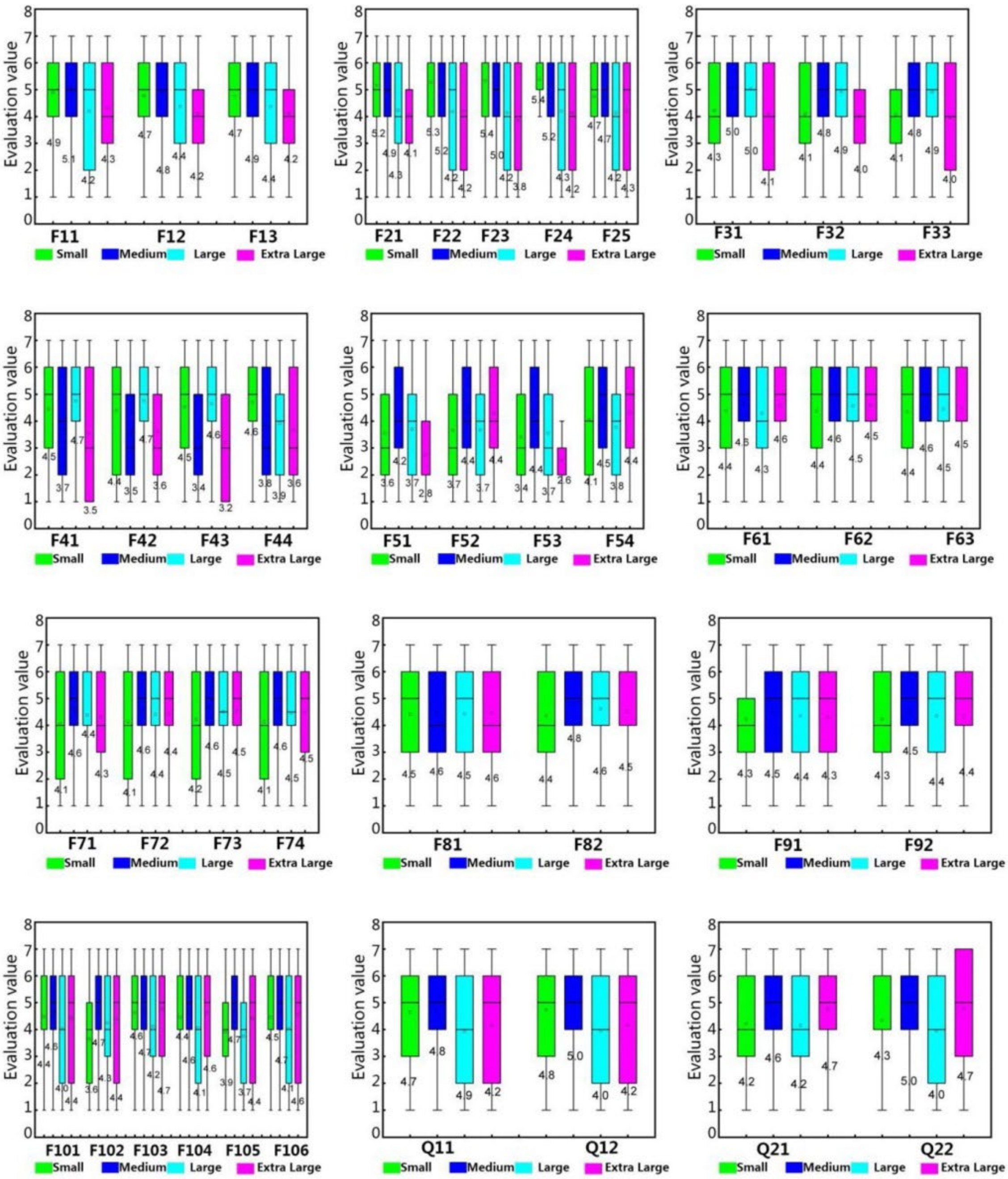
4.3.2 Model fit

A confirmatory factor analysis (CFA) of the four variables evaluated herein was performed by using the AMOS 24.0 software. If the results of the factor analysis (of the variable in analysis) were close to the theoretical analysis of the variables, the convergence validity was tested by using the model's fitting index and the normalized factor loading coefficient.

A structural equation model was developed to integrate all the AC, RS, IEQ, and QOL factors. The commonly reported eight fit parameters were evaluated to assess the model fit, including the model Chi square (X2), root mean square error of approximation (RMSEA), goodness of fit index (GFI), incremental fit index (IFI), comparative fit index (CFI), Tucker Lewis index (TLI), and adjusted goodness of fit index (AGFI) as shown in Table 9 (Hooper et al., 2008). The cut-off values to determine whether a good fit was established are also shown in Table 9. Majority of the values were within the threshold for a good fit and some were very close to the standard values. Although these were not perfectly ideal models, the fitting was determined to be acceptable (Bentler, 1982).

4.3.3 Convergence validity

According to Bagozziet et al. (1981), there are three criteria for assessing the convergence validity, which are as follows: (1) all standardized regression weights must be greater than 0.5, (2) composition reliability (CR) must be greater than 0.6, (3) average variation extraction (AVE) must be greater than 0.5. Table 10 shows that the standardized factor loading of each item with its corresponding variables was greater than 0.5 and the CR and AVE values were greater than 0.6. This shows that the convergence validity of the four scales meets the standard values. Therefore, the scales are valid and reliable.



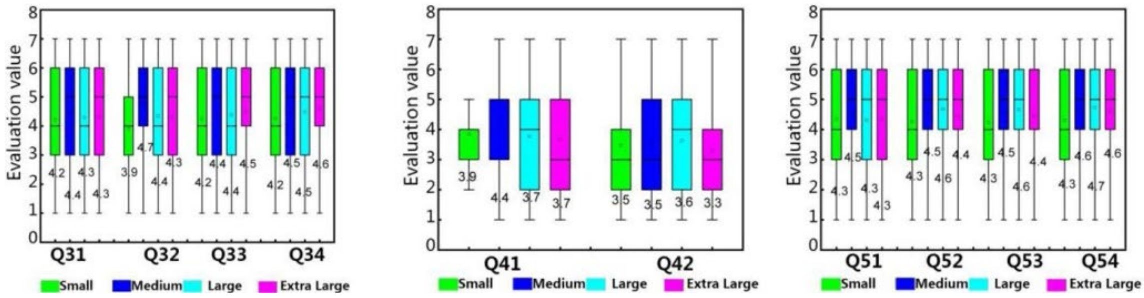


Fig. 2 Evaluation of 15 factors for the different sizes of housing regarding the AC, RS, IEQ, and QOL

Table 8 Analysis of correlation coefficients

	Architectural composi tion (AC)	Residential satisfaction (RS)	Indoor environmental quality (IEQ)	Quality of life (QOL)
AC	1			
RS	0.064**	1		
IEQ	0.659**	−0.104**	1	
QoL	0.521**	0.210**	0.521**	1

***,**, and * represent P < 0.001, P < 0.01, and P < 0.05, respectively

Table 9 Model fit index

Fit index	X2/df	RMSEA	GFI	IFI	CFI	TLI	AGFI
Good fit	<5	<0.08	>0.9	>0.9	>0.9	>0.9	>0.9
Architectural composition (AC)	4.795	0.078	0.956	0.971	0.970	0.956	0.918
Residential satisfaction (RS)	3.813	0.044	0.961	0.967	0.967	0.959	0.946
Indoor environmental quality (IEQ)	4.481	0.071	0.895	0.945	0.944	0.907	0.856
Quality of life (QOL)	4.774	0.082	0.926	0.912	0.912	0.880	0.884

4.4 Model path and intermediary analysis

4.4.1 Structural equation modelling (SEM)

Herein, we used a path analysis to find the relationships among the four variables in order to verify our initial research questions. The correction index (M) values between e7 and e10, e7 and e9, and e10 and e11 were high (Fig. 3), which represent the model fit index after correction, as summarised in Table 11. Note that all the indices achieved the standard value. The value for TLI was close to 0.90; therefore, the intermediary model was a good fit.

The interrelationships as shown in the SEM in Fig. 3 indicate that all the theoretical associations were positive and statistically significant at a 99.9% confidence interval. A significant and relatively strong association exists between the evaluation of AC and the two factors, namely, F1 planning policy and F2 design principles, while the F3 interaction with neighbours only shows a slightly weaker association. This indicates that the elderly perceived the built environment including, design and accessibility as slightly more important than neighbour relations. The evaluation of RS by the elderly was most strongly associated with the factors; F7 housing unit characteristics, F8 type and location of resident, and F9 support services, while the F6 neighbourhood environment and F4 management showed a weaker correlation. Evaluation of the IEQ by the elderly indicated strong associations among all the six factors, of which F104 temperature and F106 air quality were particularly strong. Furthermore, the SEM indicates that Q1 overall self-rated QOL and Q2 physical health were the most strongly associated factors in the evaluation of the QOL. We assumed that the elderly who were more satisfied with their QOL in general would also evaluate QOL higher in other domains as the strong associations in the model reflect. Previous studies have also reported that physical health can influence the QOL relatively more than the psychological status or social relationships (Dahlan et al., 2016; Elosua, 2011). WHO has recognized that an important goal in ageing healthily is to create environments supporting a healthy living and well-being.

Table 10 Measurement model fitting results for convergence validity

Factors	Items	Standardized factor loading	Composition reliability (CR)	Average
AC-F1	F11	0.836	0.652	0.849
	F12	0.798		
	F13	0.787		
AC-F2	F21	0.807	0.621	0.889
	F22	0.870		
	F23	0.899		
	F24	0.712		
	F25	0.616		
AC-F3	F31	0.852	0.697	0.873
	F32	0.881		
	F33	0.768		
RS-F4	F41	0.953	0.692	0.899
	F42	0.791		
	F43	0.834		
	F44	0.733		
RS-F5	F51	0.779	0.621	0.868
	F52	0.792		
	F53	0.796		
	F54	0.786		
RS-F6	F61	0.918	0.607	0.819
	F62	0.759		
	F63	0.634		
RS-F7	F71	0.771	0.605	0.818
	F72	0.663		
	F73	0.733		
	F74	0.742		
RS-F8	F81	0.822	0.607	0.621
	F82	0.621		
RS-F9	F91	0.751	0.602	0.695

	F101	0.843		
	F102	0.770		
IEQ	F103	0.818	0.716	0.938
	F104	0.932		
	F105	0.770		
	F106	0.928		
QOL-Q1	Q11	0.955	0.675	0.801
	Q12	0.662		
QOL-Q2	Q21	0.528	0.609	0.741
	Q22	0.969		
QOL-Q3	Q31	0.903	0.607	0.830
	Q32	0.740		
	Q33	0.640		
	Q34	0.668		
QOL-Q4	Q41	0.930	0.601	0.716
	Q42	0.534		
QOL-Q5	Q51	0.814	0.612	0.837
	Q52	0.763		
	Q53	0.711		
	Q54	0.710		

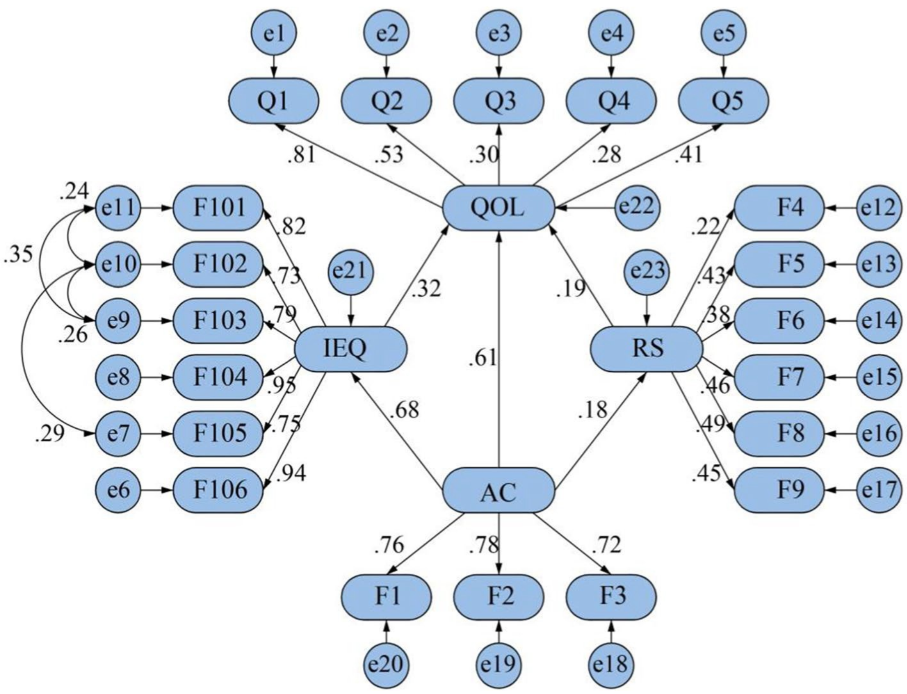


Fig. 3 Intermediary model path

Table 11 Model fit index for the intermediary model

Fit index	X2/df	RMSEA	GFI	NFI	IFI	CFI	TLI
Good fit	< 5	< 0.08	> 0.9	> 0.9	> 0.9	> 0.9	> 0.9
Model index	4.413	0.070	0.916	0.902	0.913	0.913	0.897

4.4.2 Mediation effects

To verify the mediation effect more accurately, we implemented the Bootstrap method to repeat the sampling 2000 times with a confidence interval level set to 95%. Note that the sampling method was bias corrected. These results are summarised in Table 12, wherein the total effect of the AC on the QOL was 0.863, and the 95% confidence interval = [0.823, 0.903] did not include zero, indicating that the total effect was significant. The direct effect of the AC on the QOL was 0.613, and the 95% confidence interval CI = [0.601, 0.828] did not include zero; thus, the direct effect was significant. The indirect effect of the AC on the QOL was 0.250, and as the 95% confidence interval = [0.525, 0.701] did not include zero, the indirect effect was significant. This shows that the AC had a partially indirect effect on the QOL. Combining the relationship among the four variables in Fig. 3, it can be proven that the IEQ and RS were partial intermediary variables, rather than complete intermediaries.

These results indicate that the effect of IEQ on the QOL of the elderly was greater than RS. This could be attributed to the fact that the RS is a representation of the subjective evaluation, which could have been influenced by their experiences and feelings. Conversely, the IEQ is relatively objective and realistic. As the AC had both indirect and direct positive impacts on the QOL, we infer that the location of the housing for the elderly and accessibility of resources have a significant impact on the elderly.

5 Discussion

In the present study, we used SEM to evaluate the correlations among the AC, RS, IEQ and QOL in a sample of elderly volunteers from 34 housing for the elderly locations in Northeast China, based on the results of a large-scale questionnaire.

5.1 Facility size

The results indicated that the residents of medium sized facilities gave the highest evaluation values for AC, IEQ, and QOL, while only RS was slightly higher evaluated by the elderly residents of large facilities. These results are similar to a recent study that evaluated the preferences of elderly for housing and environmental characteristics (Mulliner et al., 2020). Their results also revealed that a larger sized home was significantly less important than functionality and comfort and almost 30% of the participants wished to move to a smaller sized facility. The data derived from the interviews in the initial stage of our research revealed that the participating elderly believed that price is one of the reasons for evaluating large facilities as lower compared to smaller facilities. Another aspect raised by the residents is that the design of the housing for the elderly does not fully meet the needs of the elderly, in regard to lighting, stairs safety, and accessibility, which has been reported previously (Haanes et al., 2015). Thus, the elderly prefer to stay in their rooms as the scale is too large, which makes communication between neighbours inconvenient. We found that the facilities of some large-sized housing for the elderly were not ideal; for example, there was a smaller staff size and the location was far from the urban area, which made it difficult to access leisure and entertainment places such as shops and parks. In addition, the residents were less satisfied with the management in medium- and super large housing for the elderly than smaller sized ones. This could indicate that housing for the elderly in Northeast China lack elder care professionals. Overall, the satisfaction of medium-sized housing for the elderly was significantly higher than the other scales, thus indicating that the venue and scale should not be too large or too small, and a moderate and suitable size is optimal. These results are similar to the RS results in the studies by Sikorska (1999) and Mulliner (2020).

Table 12 Analysis of the effective values of architectural composition (AC) on the quality of life (QOL)

	Effect	S. E	LLCI	ULCI
Total effect	0.863	0.02	0.823	0.903
Direct effect	0.613	0.045	0.601	0.828
Indirect effect	0.250	0.032	0.525	0.701

5.2 Effect of the variables on the QOL

The SEM showed a good fit and the results of the subsequent Bootstrap method gave an indication of the mediation effects of the variables on the QOL. The AC significantly influences the elderly's RS, IEQ, and has a direct effect on the QOL, while the RS and IEQ have the greatest impact on the elderly's QOL, through mediating effects. A large review has concluded that most studies have shown that positive changes to the environment results in improved well-being for elderly residents (Joseph et al., 2015). Numerous studies have reported previously that people in general find thermal comfort as the most important parameter of the IEQ owing to the influence it can have on the physical and psychological wellbeing as well as behavioural aspects (Arif et al., 2016; Frontczak et al., 2012). In addition, as elderly tend to spend most of their time indoors, air quality is of utmost importance, especially since elderly are more vulnerable to exposure to indoor pollutants which can lead to sensory irritation and allergies (Frey et al., 2014). As for the correlation between the RS and QOL, Perez et al., (2001) evaluated 14 principal components of RS and found that the most important predictor of the overall RS is satisfaction with home-related attributes (including comfort, size, distribution, and insulation) and neighbourhood life and network were much weaker predictors of the RS. A similar study that also evaluated the QOL of elderly found that the distance between the rooms, furniture and fixtures, also considered as AC, influenced the QOL the most (Leung et al., 2019). Another study indicated that space planning and bathroom design influenced most QOL domains (Leung et al., 2016). Therefore, when designing and building housing for the elderly, priority should be given to their geographic location, i.e., whether it is conducive to elderly travel and visits, whether it affects the attitude of surrounding residents, and whether the interior design meets the needs of the elderly (Khodaparasti et al., 2018). In addition, our SEM results indicate that apart from the AC aspects, the most important elements of the IEQ, i.e., the temperature and air quality, also need to be taken into consideration to enhance their QOL. As the elderly experience physical decline, they have highly subjective needs for these parameters in comparison to younger people (Hwang & Chen, 2010; Rupp et al., 2015).

6 Conclusion

This study evaluated the effects of AC, IEQ, and RS on the QOL of the elderly living in different types of housing for the elderly in Northeast China through a large-scale questionnaire survey. Fifty items were extracted from the survey results of 1457 participants for an exploratory analysis of the four variables that included evaluations of the influence of different housing sizes and their rebuilt or original state. A structural equation model with 50 factors was established to examine the relationship among the AC, RS, IEQ, and QOL, as well as the influence of each factor on the overall QOL of the elderly.

Based on these analyses, the following conclusions were drawn:

1. AC, which considers the planning policy, design principles, and interactions with neighbours, significantly influences the elderly's RS, IEQ, and QOL.

2. RS and IEQ have the greatest impact on the elderly's QOL in housing for the elderly in Northeast China.

3. Considering the intermediate relationships, AC has a direct relationship with the QOL, and the RS and IEQ have a mediating effect on the QOL. Therefore, when constructing housing for the elderly, in addition to the architectural factors, designers must consider the influence of the RS and IEQ. Moreover, the influence of the AC on the elderly will ultimately affect the QOL through the RS and IEQ.

In addition to factors related to the build environment, the physical factors of the environment and the elderly's satisfaction in regard to it also have an impact on the QOL of the elderly in housing for the elderly. These results show that the IEQ and RS are intermediary variables as they indirectly affect the effect of AC on the QOL. Therefore, while some housing for the elderly do not have ideal ACs due to insufficient funds or reconstruction, managers can improve the QOL of the elderly by improving the IEQ and RS. The results of this research can contribute to the policy making and designing of housing for the elderly. However, broad knowledge is still limited, and more research is required related to the factors of housing for the elderly that specifically affect these intermediary variables and their influence on the elderly's subjective evaluations of them from different environments and backgrounds.

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Data availability The data is available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors have no conflicts of interest relevant to this manuscript.

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